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STILLBIRTH AND CAESAREAN SECTION AS NATURAL EXPERIMENTS TO IDENTIFY THE CAUSAL EFFECT OF FAMILY SIZE ON IQ AND EDUCATIONAL ATTAINMENT

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Stillbirth and caesarean section as natural experiments to identify the causal effect of family size on IQ and educational attainment

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Abstract

This paper proposes stillbirth and caesarean section as natural experiments to identity the causal effect of family size on children's IQ and educational attainment. Stillbirth is hypothesized to affect family size by shortening the intervals between subsequent births and thereby making a higher total fertility more likely. Caesarean section is hypothesized to lower total fertility by decreasing fecundity. I use data from the British National Child Development Study to estimate the causal effect of family size on various measures of IQ at age 7, 11, and 16 and completed years of schooling at age 33. OLS estimates show that family size has a negative effect on all IQ measures and completed years of schooling. However, 2SLS models which use stillbirth and caesarean section as instruments for family size show no causal effect of family size on IQ and educational attainment.

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I. Introduction

The relationship between family size and children's outcomes has received considerable attention in economics, psychology, and demography. In economics, the *Quantity-Quality Trade-Off* theory hypothesizes that due to increasing marginal costs of children parents face a choice between having few "high-quality" children or many "low-quality" children (see, Becker and Lewis 1973; Becker and Tomes 1976). In psychology, the *Confluence Model* hypothesizes that having many siblings creates an intellectually inferior climate which depresses children's IQ and schooling outcomes (see, Zajonc and Markus 1975; Zajonc 1976). Finally, in demography the *Resource Dilution Hypothesis* claims that large families drain parents' economic, social, and time resources, thereby leading to lower parental inputs in children and poorer child outcomes (see, Blake 1985; Downey 2001).

The implication of all the different theories is that, for different reasons, family size should have a negative causal effect on child outcomes. Many empirical studies find that family size is negatively correlated with children's IQ (for reviews see Cicirelli 1978; Ernst and Angst 1983; Heer 1985; Steelman 1985; Steelman et al. 2002). Many studies also find that family size in negatively correlated with completed schooling. Table A1 summarizes findings from a range of descriptive empirical studies in demography, sociology, and economics which suggest that increasing family size by one child reduces completed years of schooling by approximately 0.1-0.3 years.

However, it remains unclear if the results from these descriptive studies represent causal effects of family size on child outcomes. If, for example, family size is correlated with unobserved socioeconomic, psychological, or physiological attributes in families that jointly affect IQ and schooling, estimates of the effect of family size on IQ and schooling from Ordinary Least Squares (OLS) regression or similar methods will be biased due to endogeneity.

In recent years a range of studies have attempted to recover consistent causal estimates of the effect of family size on child outcomes. These studies use one of two identification strategies. One type of studies mostly by sociologists uses sibling data to control for unobserved family characteristics shared by siblings. However, these studies are less useful because fixed effect sibling models (e.g., Lindert 1977; Olneck and Bills 1979; Guo and VanWey 1999) difference out family size (which is shared by siblings) and random effect sibling models (e.g., de Graaf and Huinink 1992; Sandefur and Wells 1999; Sieben, Huinink, and de Graaf 2001) assume that family size is uncorrelated with the unobserved family characteristics.

Other studies, mostly by economists, exploit natural or quasi-experiments which induce variation in family size that does not have a direct effect on children's IQ or schooling to identify the causal effect of family size on child outcomes. The two most widely used natural experiments in this literature are twin births (Rosenzweig and Wolpin 1980; Angrist, Lavy, and Schlosser 2005, 2006; Black, Devereaux, and Salvanes 2005; Cáceras-Delpiano 2006; Li, Zhang, and Zhu 2007) and the sex composition of the sibship (Angrist, Lavy, and Schlosser 2005, 2006; Goux and Maurin 2005; Conley and Glauber 2006). As it is reasonable to assume that the probability of a twin birth and children's sex is randomly assigned by nature, these natural experiments affect family size but have no direct effect on child outcomes. As I discuss below, findings from these studies on the effect of family size on child outcomes are inconclusive.

This paper extends previous research by exploiting two natural experiments that have not previously been used to identify the causal effect of family size on child outcomes: Stillbirth and caesarean section. Some previous studies have used miscarriage as a natural experiment to estimate the impact of teenage motherhood on women's outcomes (e.g., Hotz, Mullin, and Sanders 1997; Goodman, Kaplan, and Walker 2004; Hotz, McElroy, and Sanders 2005; Levene, Emery, and Pollack 2007). The idea in these studies is that a miscarriage is a random event which assigns some women who would have become teenage mothers not to become teenage mothers.

In this paper I use stillbirth as an instrument for women's total fertility. A stillbirth is defined as a spontaneous abortion in or after 20 weeks' pregnancy whereas a miscarriage is a spontaneous abortion before 20 weeks' pregnancy (Goldenberg, Kirby, and Culhane 2004). In the *National Child Development Study* (NCDS, a longitudinal study of children born in the United Kingdom during the first week of March 1958) I use in the empirical analysis, the mothers of the NCDS children in my sample who report having experienced a stillbirth prior to the birth of the NCDS child have 0.509 more children than mothers who have not experienced a stillbirth (see Table 1). Below, I argue that the reason why total fertility is higher among these mothers is that they change their fertility behavior, first, by having shorter spacing between subsequent births (a "replacement" effect) and, second, by having more pregnancies than initially expected to insure against future losses (a "hoarding" effect).

My second instrument is having given birth by caesarean section. Caesarean section has not previously been used as an instrument for family size. It is well-documented in the medical literature that caesarean section has a negative effect on women's total fertility by leading to a higher incidence of miscarriages and stillbirths in later pregnancies, more birth complications, and more problems conceiving (e.g., Kennare, Tucker, and Heard 2007). This is also the case in my NCDS sample in which mothers who have given birth by caesarean section before or in the delivery of the NCDS child under study have 0.752 fewer children than mothers who have not given birth by caesarean section (see Table 1). Furthermore, in the cohorts of mothers studied in this paper (who had their children in the 1950s and 1960s) the risk of caesarean section was determined by medical conditions during pregnancy or during birth that are unrelated to mothers' socioeconomic characteristics. Consequently, caesarean section is a potential instrument for family size that has no direct effect on child outcomes.

In addition to proposing two new instruments for family size, the paper makes three advances to the existing literature. First, I use an especially appropriate dataset. The NCDS was originally designed as a medical survey which means that, in addition to standard socioeconomic information, the data also includes very detailed information on the obstetric history (including information on previous stillbirths, caesarean section, induced abortions, and risk factors associated with these conditions) of the NCDS mothers obtained from medical records and midwives. Second, I analyze the effect of family size on several child outcomes: IQ at age 7, 11, and 16 (measured by math, reading, and general ability measures), and years of completed schooling at age 33. Third, since I have multiple instruments which tap different sources of potentially exogenous variation in family size I can examine the validity of the instruments. Most existing studies use only one instrument which means that there are no overidentifying restrictions which can be used to test for instrument validity (studies which use multiple instruments are Angrist, Lavy, and Schlosser 2005, 2006; de Haan 2005; Black, Devereaux, and Salvanes 2007a).

My empirical analysis shows that, when also controlling for a range of family background variables, OLS estimates of the effect of family size on children's IQ at age 7, 11, and 16, and years of completed schooling at age 33 are highly significant and negative. These results indicate that there is a quantity-quality trade-off. However, when I instrument family size by stillbirth and caesarean section in Two-Stage Least Squares (2SLS) models I find no effect of family size on IQ and educational attainment. My results then suggest that there is no trade-off between child quantity and quality, at least not in the birth cohort studied.

II. Previous Research

This section reviews findings from previous studies on the effect of family size on IQ and educational attainment.

Most descriptive studies find that family size is negatively correlated with IQ and completed schooling. A large psychological literature has demonstrated that family size is negatively correlated with IQ (see Cicirelli 1978; Ernst and Angst 1983; Heer 1985; Steelman 1985; Steelman et al. 2002). Furthermore, family size is often found to be negatively correlated with completed schooling. Table A1 summarizes findings from a range of descriptive studies which typically estimate the negative effect of increasing family size by one on completed years of schooling to lie in the range of 0.1-0.3 years of schooling.

Findings from existing studies which explicitly address the problem of whether the effect of family size on child outcomes is causal are mixed. Rosenzweig and Wolpin (1980), Lee (forthcoming), and Li, Zhang, and Zhu (2007) find clear evidence of a negative effect of family size on children's schooling in India, South Korea, and China. By contrast, Goux and Maurin (2005), Conley and

Glauber (2006), Cáceres-Delpiano (2006), and Black, Devereaux, and Salvanes (2007a) find weak evidence of a negative effect in France, the US, and Norway. By contrast, Angrist, Lavy, and Schlosser (2005, 2006), Black, Devereaux, and Salvanes (2005), and de Haan (2005) find no effect in Israel, Norway, the US, and the Netherlands. In addition to these studies, Qian (2004) uses relaxations in China's One Child Policy as an instrument for family size and reports a positive effect of family size on school enrollment in China. Consequently, findings from previous studies which use natural experiments to identify the causal effect of family size on child outcomes are inconclusive. However, given the large variation in societal contexts and instruments in these studies it is perhaps not surprising that findings differ. Tentatively, there is some evidence that the quantity-quality-trade-off exists in developing countries but is of lesser importance in developed countries.

III. Instruments

The demand for children is often seen in economics as a function of preferences for children and the monetary, non-pecuniary, and opportunity costs of children (Becker and Lewis 1973; Becker and Tomes 1976). In addition to these factors also *fecundity*, i.e., the individual's innate or environmentally influenced ability to have children, affects realized fertility (Bongaarts 2001). Consequently, holding constant the total costs of children, one would expect that realized fertility depends on how many children an individual (or couple) desires (preferences) and how many children this individual (or couple) is capable of having (fecundity). The idea behind my instruments is to use two events that induce exogenous shocks to preferences and fecundity to identify the causal effect of family size on child outcomes: Stillbirth and caesarean section.

Stillbirth

A stillbirth is defined as a spontaneous abortion in or after 20 weeks' pregnancy and occurs in about 0.7 percent of all births (Goldenberg, Kirby, and Culhane 2004). The risk of stillbirth is sometimes found to be associated with prior stillbirth, smoking and alcohol behavior, maternal obesity, mother's age, diabetes, and socioeconomic status (e.g., Stephansson et al. 2001; Wisborg et al. 2001; Kiran et al. 2005). Furthermore, a number of biological conditions during pregnancy such as congenital anomalies, infections, placental abruption, and umbilical cord accidents cause stillbirth (Goldenberg, Kirby, and Culhane 2004). Even after careful examination the causes of up 50 percent of all stillbirths remain unknown.

TABLE 1 HERE

There is evidence to suggest that, when conditioning on the risk factors known to be correlated with stillbirth, the risk of stillbirth is largely random. Previous studies have exploited this mechanism to treat miscarriage as an instrument for teenage motherhood (see Hotz, Mullin, and Sanders 1997; Goodman, Kaplan, and Walker 2004; Hotz, McElroy, and Sanders 2005; Levene, Emery, and Pollack 2007). These studies use miscarriage as an instrument for fertility *timing*, i.e., as a natural experiment which randomly assigns women to become mothers during their teens. In this paper I use stillbirth as an instrument for women's total fertility. In this setup stillbirth has a different effect on total fertility. Table 1 shows that in the NCDS sample I analyze mean family size for mothers who have not experienced a stillbirth is 3.322 and mean family size for mothers who have experienced a stillbirth is 3.831. The mean difference in family size is 0.509 and shows that women who were randomly exposed to stillbirth have higher total fertility than women who were not exposed to stillbirth. If stillbirth affects family size but is unrelated to children's IQ and schooling then stillbirth might be a valid instrument for family size.

There are several plausible explanations why stillbirth leads to higher total fertility. Theoretically, Bhat (1998) suggests that two effects drive the positive impact of stillbirth on total fertility: A short-term "replacement" effect of the lost child (which manifests in shorter spacing between the stillbirth and the next birth) and a long-term "hoarding" effect which means that mothers have more children than anticipated and faster. The hoarding effect implies that stillbirth makes mothers realize their planned fertility sooner which in turn means that they are more likely to have larger families. In the NCDS data the birth spacing between the NCDS child and the next younger/older sibling is significantly shorter if mothers have experienced a stillbirth than if mothers have not experienced a stillbirth.[1] Furthermore, mothers who have experienced a stillbirth have significantly higher total fertility. This higher total fertility is not trivial since stillbirth is often also associated with depressive symptoms in women (e.g., Hughes, Turton, and Evans 1999; Turton et al. 2001) and an increasing risk of a second stillbirth, more birth complications, and problems conceiving, see e.g., Paz et al. 1992; Hassan and Killick 2005; Kashanian et al. 2006).

The idea behind the stillbirth instrument is that stillbirth represents an exogenous shock to family size but, conditioning on behavioral factors associated with stillbirth, is assumed not to have any direct effect on children's IQ and schooling. As described above and tested below stillbirth has a

[1] It is not possible in the NCDS to determine if the pregnancy prior to the birth of the NCDS child resulted in a stillbirth or if the stillbirth occurred further back in time. In the NCDS the spacing between the NCDS child and the next younger/older sibling is measured on a nine-point ordered scale (1 = under 1 year, 2 = 1 year but under 2 years, 3 = 2 years but under 3 years, 4 = 3 years but under 4 years, 5 = 4 years but under 5 years, 6 = 5 years but under 10 years, 7 = 10 years but under 15 years, 8 = 15 years but under 20 years, and 9 = 20 years or more). When also controlling for parents' socioeconomic characteristics, mothers who have experienced a stillbirth score .731 ($p < 0.001$) lower on this birth spacing scale than mothers who have not experienced a stillbirth.

positive effect on family size. This means that stillbirth is a candidate instrument for family size. To be valid the risk of stillbirth should also be uncorrelated with parental socioeconomic characteristics that affect children's IQ and schooling. Table A2 shows results from a linear probability model in which the probability of having experienced a stillbirth in the NCDS sample is regressed on all parental socioeconomic variables (log family income, father and mother's education, father's occupation, and family type) and the observed risk factors (previous induced abortion, mother's smoking behavior and Body Mass Index (BMI), and mother and father's age at the birth of the NCDS child). The table shows, first, that the risk of stillbirth is uncorrelated with all observed socioeconomic variables and, second, that three risk factors: Previously having had an induced abortion and mother and father's age at the birth of the NCDS child increase the likelihood of stillbirth. This result provides some evidence that the risk of stillbirth is unrelated to socioeconomic factors that affect children's IQ and schooling. Results from overidentification tests and reduced-form equations presented below support this impression. However, even though my analysis indicates that stillbirth is a valid instrument for family size stillbirth might still be correlated with some unobserved genetic, physiological, or socioeconomic attributes in mothers and families that have a direct effect on child outcomes. In the present analysis I have to assume that the impact of these factors is neglible.

Caesarean section

Caesarean section is a type of childbirth in which a surgical incision is made through a mother's abdomen and uterus to deliver a child. Factors which lead to caesarean section include fetal distress, birth complications, prolonged labor, and multiple births. Giving birth by caesarean section has a negative effect on women's fecundity. Women who have delivered by caesarean section have lowered fertility, higher risks of stillbirths in subsequent pregnancies, and a higher incidence of birth complications (e.g., Hemminki 1996; Smith, Pell, and Dobbie 2003; Kennare, Tucker, and Heard 2007). In the NCDS sample total fertility is lower for mothers who have given birth by caesarean section compared to mothers who have not given birth by caesarean section. Table 1 shows that mothers who have given birth by caesarean section on average have 0.752 fewer children than women who have not given birth by caesarean section.

I use caesarean section as the second instrument for family size. Unlike stillbirth which is hypothesized as a shock to women's reproductive behavior, I use caesarean section as a shock to women's fecundity. The identifying assumption behind this instrument is that caesarean section affects family size but is unrelated to parental characteristics that affect children's IQ and schooling. As described above, women who have given birth by caesarean section have significantly fewer children than women who have not given birth by caesarean section. This difference suggests that caesarean section is a candidate instrument for family size. To be valid the likelihood of giving birth by caesarean section should be uncorrelated with parental socioeconomic characteristics that affect children's IQ and schooling. Table A2 shows results from a linear probability model of the likelihood of having given birth by caesarean section as a function of all observed parental socioeconomic and risk variables. As with stillbirth, the probability of having given birth by caesarean section is uncorrelated with all parental socioeconomic characteristics and only the age of the mother at the birth of the NCDS child has a significant effect on the risk of caesarean section. Further overidentification tests and results from reduced-form equations shown below support the hypothesis that caesarean section does not have any direct effect on child outcomes.

A potential threat to the caesarean section instrument is that children who are delivered by caesarean section already before birth might have characteristics that are negatively correlated with

IQ and schooling. For example, caesarean section is known to be correlated with low birthweight which might have a direct effect on children's IQ and schooling. Furthermore, some types of fetal distress which increase the likelihood of birth by caesarean section might also be correlated with maternal characteristics (obesity, age at birth, smoking, drinking, etc.) which affect IQ and schooling directly. However, the richness of the NCDS data means that I can control directly for some of these intervening factors: Children's birthweight, mother's BMI and age at birth of the NCDS child, and prior smoking history. Finally, although in recent years caesarean section has become a type of delivery that women themselves may choose (which might lead to a self-selection of women into this type of delivery, e.g., Joseph et al. 2006), this is very unlikely to be the case for the NCDS mothers who had their children in the 1950s and 1960s.

Combining the stillbirth and caesarean section instruments

In the empirical analysis I use both stillbirth and caesarean section as instruments for family size. Several previous studies have combined two instruments for family size, typically twin birth and the sex composition of the sibship (e.g., Angrist, Lavy, and Schlosser 2005, 2006; de Haan 2005; Black, Devereaux, and Salvanes 2007a). This paper takes a similar approach by combining two instruments that are believed to represent different types of exogenous shocks to women's reproductive behavior and their fecundity.

The advantage of having multiple instruments is that they provide exclusion restrictions for each other that can be used to assess the validity of the instruments. For example, stillbirth is invalid as an instrument if the risk of stillbirth is correlated with unobserved parental characteristics that have a direct effect on children's IQ and schooling. Operationally, this situation implies that stillbirth is correlated with the residuals from a 2SLS regression which captures these unobserved characteristics. The same scenario applies to caesarean section. However, if stillbirth and caesarean section represent two different types of exogenous shocks to family size it is unlikely that they are correlated with the same unobservables that might render them individually invalid as instruments. Conventional tests for overidentifying restrictions assume that at least one instrument is valid and tests the validity of the remaining instruments. However, these tests are less useful if all instruments are biased in the same direction. Consequently, having multiple instruments which capture different types of exogenous shocks to family size increases the reliability of overidentification tests.

Since this paper introduces two new instruments for family size it would have been interesting to compare the results obtained using these instruments with the results obtained using the twin and sex composition instruments. Unfortunately, it is not possible to make this comparison with the NCDS sample. Although the NCDS includes information on twin births, the small sample size means that the twin instrument does not have any significant effect on family size in the first stage regressions. Furthermore, it is also possible to construct a dummy variable for same-sex siblings in the two first births in the NCDS families. However, this variable is only weakly significantly ($p < 0.10$) correlated with family size in the sub sample of NCDS families with 3 or more children. Consequently, I am unable to compare my results using the stillbirth and caesarean section instruments with results from the twin and sex composition instruments.

IV. Data and Variables

I analyze data from the *National Child Development Study* (NCDS). The NCDS is a panel survey of all children (approximately 17,500) born during the first week of March 1958 in the United Kingdom (see Plewis et al. 2004 for more information on the NCDS). Follow-ups have been carried out in 1965 (NCDS1), 1969 (NCDS2), 1974 (NCDS3), 1981 (NCDS4), 1991 (NCDS5), and 1999/2000 (NCDS6).

The NCDS began in 1958 as the *Perinatal Mortality Survey*, a medical survey designed to provide data on the social and obstetric factors associated with stillbirth and death in early infancy. Information on mothers' past obstetric history, antenatal care and abnormalities during pregnancy, and previous stillbirths was collected by the midwives who assisted with the delivery of the NCDS child. Information came from all available medical records and interviews with mothers themselves. Because the NCDS began as a medical survey it has more detailed and reliable information on mothers' fertility and obstetric history than most population surveys. This fact enables me to obtain accurate information on whether mothers have previously experienced stillbirth and caesarean section.

The gross NCDS sample analyzed in this paper consists of 4,848 respondents. This sample includes all NCDS respondents who have non-missing information on the various IQ measures at age 7, 11, and 16, educational attainment at age 33, and family size.

TABLE 2 HERE

Variables

Table 2 shows descriptive statistics for all variables in the analysis. The outcome variables are NCDS children's IQ at age 7, 11, and 16, and years of completed schooling at age 33. At age 7 and 16 children took a math and reading ability test. At age 11 children took a general ability test. I refer to all of these tests as IQ tests although they test different aspects of IQ. The correlations between children's IQ scores throughout childhood range from 0.409 to 0.675 (all with $p < 0.001$) suggesting that children maintain their relative position in the distributions of IQ over time. Since the different IQ variables use different scales I standardize the variables to have mean 0 and standard deviation 1. Educational attainment is measured by years of completed schooling at age 33 (mean = 11.834, SD = 1.812)

The key explanatory variable is *family size*. This variable summarizes the total number of children in the NCDS child's family (that is, the NCDS child and all brothers and sisters). The NCDS also includes information on birth order but I exclude this variable since it is very highly correlated with family size (see also de Haan 2004; Black, Devereaux, and Salvanes 2005, 2007b).

The two instruments for family size are defined as follows. *Stillbirth* is a dummy variable taking the value 1 if the mother of the NCDS child has experienced a stillbirth or neonatal death prior to the birth of the NCDS child, and 0 otherwise. Table 1 shows that 5.4 percent of mothers (n = 260) have experienced a stillbirth. *Caesarean section* is a dummy variable taking the value 1 if the mother of the NCDS child has delivered the NCDS child or any previous child by caesarean section. Table 1 shows that 2.9 percent of mothers (n = 142) have delivered by caesarean section.

The NCDS also includes information on some of the risk factors associated with stillbirth. First, I include a variable measuring how often mothers smoked prior to their pregnancy with the NCDS child. This variable measures smoking on a scale with the values 1 = non-smoker, 2 = 1-4 daily cigarettes, 3 = 5-9 daily, 4 = 5-9 daily, 5 = 10-14 daily, 6 = 15-19 daily, 7 = 20-24 daily, 8 = 25-29 daily, and 9 = 30 or more daily. Second, I include a variable which measures mothers' Body Mass

Index (BMI) in 1958.[2] Third, I include two variables measuring mother and father's age at the birth of the NCDS child. Fourth, I include a dummy variable for mothers who have previously had one or more induced abortions. Other known risk factors are alcohol consumption and diabetes. Unfortunately, the NCDS does not include information on mothers' alcohol consumption and there are too few mothers in the NCDS sample with diagnosed diabetes to create a useful control variable.

Finally, I include a range of parental socioeconomic and child controls. The parental socioeconomic controls include the natural logarithm of net monthly family income in Pounds Sterling in 1974, father and mother's education measured by years of completed schooling, a set of dummies for father's occupational position, and a dummy variable for single-parent households. The child controls are birthweight in kilograms and the child's sex (with a dummy variable for women). In addition to these variables, I also include dummy variables indicating missing values on mother's BMI, mother and father's age at the birth of the NCDS child, log family income, father and mother's education, father's occupation, and the child's birthweight.

V. Empirical Strategy

I use standard OLS regression to carry out a descriptive analysis of the effect of family size on IQ and educational attainment and 2SLS regression for the Instrumental Variable (IV) analysis which uses stillbirth and caesarean section as instruments for family size. Tests for instrument relevance and validity and results from reduced-form models are presented below where appropriate.

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[2] Mother's BMI is imprecisely measured in the NCDS because mother's weight in 1958 was recorded in the measurement unit stones (1 stone ~ 14 pounds ~ 6.35 kilograms) and in intervals. However, the mean BMI for mothers in the sample is 23.023 which is in the middle of the normal range for BMI (20-25).

Similar to previous studies, it should be noted that my 2SLS estimates are Local Average Treatment Effects (LATEs) of family size on IQ and educational attainment (Imbens and Angrist 1994). This means that the analysis identifies the average effect of increasing family size by one on children's IQ and educational outcomes for families that have been subjected to the "treatments", i.e., stillbirth and caesarean section. My instruments, like the twin birth and, to a lesser extent, the sex composition instrument, pertain to relatively rare events, and the causal effects of family size I estimate cannot readily be generalized to larger populations.

VI. Results

I estimate four types of models. The first type of model are baseline OLS regressions of the effect of family size on children's IQ at age 7, 11, and 16, and years of completed schooling. The second and third types of models are 2SLS models which include stillbirth and caesarean section separately as instruments for family size. The fourth type of models includes both stillbirth and caesarean section as instruments for family size.

TABLE 3 HERE

Table 3 shows results from the baseline OLS models. I find that family size has a highly significant negative effect on all standardized IQ measures and educational attainment. Measured in fractions of a standard deviation in the distribution of the IQ measures the effect of family size is lowest for math ability at age 7 and highest for reading ability at age 16. Interestingly, the negative effect of family size is stronger for reading ability than for math ability both at age 7 and 16. The size of the negative effect of family size on completed years of schooling estimated from OLS (-0.179) corresponds to the typical descriptive estimates reported in Table A1. The results from the control variables are similar to most previous studies: Children have higher IQ and more schooling if they have higher birthweight, parents have higher education, fathers are in higher occupations, and mothers have lower BMI and are older at the birth of the NCDS child.

TABLE 4

However, even after conditioning on the parental and child controls it remains unknown if the OLS models estimate unbiased causal effects of family size on IQ and educational attainment. Table 4 reports results from 2SLS models in which I use stillbirth and caesarean section as instruments for family size. The first row in the table summarizes the OLS estimates of the effect of family size on IQ and educational attainment from Table 2. The second and third rows show the estimated effect of family size from the 2SLS model when using stillbirth and caesarean section separately as instruments for family size, and the fourth row shows results when using both instruments.

Irrespective of which configuration of the instruments I use the general impression from the 2SLS models is that family size does not have any causal effect on IQ and educational attainment. When used separately both the stillbirth and caesarean section instruments lead to insignificant estimates of the effect of family size on all IQ measures and schooling. This is the case even though the instruments have different predictive power. The *F*-statistic for the excluded instrument in the first stage (Staiger and Stock 1997) has a value of 7.71 for the stillbirth instrument and 35.91 for the caesarean section instrument. These *F*-statistics suggest that the stillbirth instrument is borderline weak while the caesarean section instrument is very strong. With the exception of math ability at age 7, the coefficients for the family size effect (though never significant) are consistently higher when using the stillbirth instrument than when using the caesarean section instrument. This result indicates that the two instruments might capture different LATEs.

Table 4 also reports results from 2SLS models in which I use both stillbirth and caesarean section as instruments for family size. With the exception of math ability at age 7, the estimated effects of family size from these models are very similar in magnitude to the effects from the OLS models. However, the standard errors of the 2SLS estimates are much larger and none of the estimated effects of family size from the 2SLS models are significant at the conventional level (the effects of family size on math ability at age 7 and math and reading ability at age 16 are significant at the 0.10 percent level). Consequently, the analysis provides little evidence that family size has a negative effect on children's IQ and educational attainment. This result is similar to that reported in several previous studies using the twin and sex composition instruments (Angrist, Lavy, and Schlosser 2005, 2006; Black, Devereaux, and Salvanes 2005; de Haan (2005).

The analysis shows that there is no negative effect of family size on family size. But how do the stillbirth and caesarean section instruments perform? Table 4 also shows results from the first stage regression, overidentification tests, and reduced-form models for the 2SLS models that use both stillbirth and caesarean section as instruments for family size. When also including the parental and child controls in the first stage regression both stillbirth and caesarean section have independent and significant effects on family size (since I use the same observations in all models the first stage results are identical across models). Table 4 shows that when also conditioning on all controls stillbirth increases family size by 0.338 ($p < 0.01$) and caesarean section reduces family size by 0.900 ($p < 0.001$). The F-statistic for the excluded instruments is 22.76 suggesting that the instrument mix has good explanatory power.

In addition to their explanatory power the instruments must also be valid; i.e., they must only affect children's IQ and schooling through family size. Table 4 also reports *p*-values from overidentification tests for each outcome variable. The idea behind my instruments is that they should affect family size through exogenous shocks to women's reproductive behavior and fecundity. Stillbirth and caesarean section thus represent different types of shocks to fertility that provides useful exclusion restrictions for each other. As is evident from the table the instrument mix passes the overidentification test in all models, thereby suggesting that stillbirth and caesarean section are valid instruments for family size. To further assess the validity of the instruments I also estimate reduced-form models for each IQ and schooling outcome. The reduced-form model is an OLS regression of the IQ or schooling outcome on the parental and child controls, the dummies for stillbirth and caesarean section, but excluding the endogenous variable family size. The idea in the reduced-form model is that the instruments should be uncorrelated with the outcome variable, i.e., they should *not* affect IQ or schooling directly. Results from the reduced-form models presented at the bottom of Table 4 show that, with the exception of a weakly significant negative effect of caesarean section on math ability at age 7, the instruments have no direct effect on any of the IQ and schooling outcomes. This finding further supports instrument validity.

VII. Discussion

This paper seeks to estimate the causal effect of family size on children's IQ during childhood and completed schooling. Theories in economics, psychology and demography argue that there should be a negative causal effect of family size on IQ and schooling, and many descriptive studies support this argument. However, descriptive studies do not address the problem of whether the observed correlation between family size and IQ and schooling is causal.

In this paper I follow the literature in economics which exploits natural experiments that affect family size but are unrelated to children's IQ and schooling to identify a causal effect of family size on child outcomes. I introduce two instruments that have not previously been used in this literature: Stillbirth and caesarean section. The instruments represent different types of exogenous shocks to family size: Stillbirth changes women's reproductive behavior due a combined "replacement" and "hoarding" effect and caesarean section reduces fecundity. Both instruments affect family size but have no direct effect on children's IQ and schooling.

My empirical analysis using the National Child Development Study (NCDS) shows, first, that mothers who have experienced a stillbirth have significantly more children than women who have not experienced a stillbirth, and second, that women who have given birth by caesarean section have significantly fewer children than women who have not had this type of delivery. Furthermore, descriptive OLS regressions show that family size has a negative significant effect on IQ at age 7, 11, and 16 as well as completed schooling at age 33. However, when I use stillbirth and caesarean section as instruments for family size to account for the endogeneity of family size I consistently find no effect of family size on IQ and schooling. Like several previous studies which also exploit natural experiments I find no evidence of a quantity-quality trade-off.

The present analysis has attempted to shed new light on the alleged negative relationship between family size and child outcomes by exploiting two natural experiments that have not previously been used in this context. The connection between family size and child outcomes is important both in theoretical models of family formation and in family policies. The conventional wisdom that large families lead to less favorable child outcomes has been challenged in a number of recent studies, at least for developed countries. However, while these recent studies have been useful with respect to determining if the link between family size and child outcomes is causal, they all, including the present study, identify LATEs. Future research should look for new and possibly more encompassing natural experiments that can be used to identify broader causal effects of family size on child outcomes.

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Table 1
Mean Family Size by Stillbirth and Caesarean Section status

Status:	Stillbirth	Caesarean section
Yes	3.831	2.620
No	3.322	3.372
Difference	0.509*	-0.752*

Notes: * Difference in Means is significant at $p < 0.001$. Number of observations = 4,448

Table 2
Descriptive Statistics. Means and Standard Deviations

	Mean	Standard Deviation
Outcome measures		
Math ability, age 7 (Standardized)	0	1
Reading ability, age 7 (Standardized)	0	1
General ability, age 11 (Standardized)	0	1
Math ability, age 16 (Standardized)	0	1
Reading ability, age 16 (Standardized)	0	1
Years of schooling	11.834	1.812
Family size	3.350	1.753
Stillbirth	0.054	0.225
Caesarean section	0.029	0.169
Induced abortion	0.115	0.319
Mother smoked before pregnancy with NCDS child	2.322	1.851
Mother’s BMI at birth of NCDS child	23.023	3.448
Missing data on mother’s BMI	0.075	0.263
Mother’s age at birth of NCDS child	27.382	5.659
Father’s age at birth of NCDS child	30.499	6.224
Missing data on father’s age at birth of NCDS child	0.049	0.217
Missing data on mother’s age at birth of NCDS child	0.023	0.150
Log family income	4.535	1.618
Missing data on log family income	0.209	0.407
Father’s years of schooling	9.798	1.649
Mother’s years of schooling	9.832	1.292
Missing data on father’s years of schooling	0.039	0.193
Missing data on mother’s years of schooling	0.017	0.128
Father’s occupation		
Professional	0.029	0.167
Managerial and Technical	0.114	0.318
Skilled non-manual	0.089	0.284
Skilled manual	0.505	0.500
Partly skilled	0.122	0.327
Unskilled	0.078	0.269
Other or missing data on father’s occupation	0.063	0.244
Single-parent household	0.027	0.162
Child’s birthweight in kilograms	3.328	0.518
Missing data on birthweight	0.050	0.217
Child’s sex (1 = female)	0.527	0.499

Notes: Number of observations = 4,848.

Table 3
OLS Estimates of the Effect of Family Size on IQ and Years of Completed Schooling

Outcome	Math ability, age 7	Reading ability, age 7	General ability, age 11	Math ability, age 16	Reading ability, age 16	Years of schooling
Family size	-0.029***	-0.111***	-0.101***	-0.090***	-0.147***	-0.179***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.014)
Log family income	0.021	0.014	0.018	0.006	0.033**	0.045*
	(0.013)	(0.013)	(0.012)	(0.012)	(0.012)	(0.023)
Father's years of schooling	0.025*	0.035***	0.047***	0.057***	0.040***	0.067***
	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)	(0.019)
Mother's years of schooling	0.058***	0.043***	0.079***	0.080***	0.084***	0.161***
	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)	(0.022)
Father's occupation						
Professional	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Managerial and Technical	0.032	-0.009	0.044	-0.122	-0.030	-0.372*
	(0.096)	(0.093)	(0.092)	(0.091)	(0.090)	(0.167)
Skilled non-manual	0.010	0.014	-0.055	-0.270**	-0.032	-0.564***
	(0.102)	(0.098)	(0.097)	(0.096)	(0.095)	(0.177)
Skilled manual	-0.079	-0.126	-0.151	-0.413***	-0.197*	-0.745***
	(0.094)	(0.091)	(0.090)	(0.089)	(0.088)	(0.164)
Partly skilled	-0.084	-0.196*	-0.222*	-0.438***	-0.348***	-0.850***
	(0.102)	(0.098)	(0.097)	(0.096)	(0.095)	(0.176)
Unskilled	-0.163	-0.315**	-0.464***	-0.595***	-0.497***	-1.136***
	(0.107)	(0.103)	(0.102)	(0.101)	(0.099)	(0.185)
Single-parent household	-0.187	-0.325*	-0.089	-0.229	0.028	-0.051
	(0.155)	(0.150)	(0.148)	(0.147)	(0.145)	(0.270)
Child's birthweight in	0.195***	0.193***	0.187***	0.165***	0.183***	0.140**
kilograms	(0.023)	(0.028)	(0.027)	(0.027)	(0.027)	(0.051)
Child's sex (1 = female)	-0.039	0.277***	0.211***	-0.196***	-0.011	-0.268***
	(0.029)	(0.028)	(0.027)	(0.027)	(0.027)	(0.050)
Induced abortion	-0.096*	-0.062	-0.059	-0.052	-0.004	0.062

	(0.045)	(0.043)	(0.043)	(0.043)	(0.042)	(0.078)
Mother smoked before	-0.003	-0.011	-0.023**	-0.020*	-0.013	-0.060***
pregnancy with NCDS child	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.014)
Mother's BMI at birth of	-0.008	-0.013	-0.015***	-0.013**	-0.014***	-0.014
NCDS child	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.008)
Mother's age at birth of	0.006	-0.001	0.013***	0.014***	0.022***	0.021**
NCDS child	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.007)
Father's age at birth of NCDS	0.001	0.007	-0.001	0.0004	-0.002	0.001
child	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.007)
Adj. R^2	0.04	0.101	0.120	0.132	0.160	0.112

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ (two-tailed). Number of observations = 4,448. All models also control for missing data on log family income, father's schooling, mother's schooling, father's occupation, birthweight, mother's smoking behavior, mother's BMI, and mother and father's age at birth of NCDS child.

Table 4
2SLS Estimates of the Effect of Family Size on IQ and Years of Completed Schooling

Outcome	Math ability, age 7	Reading ability, age 7	General ability, age 11	Math ability, age 16	Reading ability, age 16	Years of schooling
Family size (OLS)	-0.029***	-0.111***	-0.101***	-0.090***	-0.147***	-0.179***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.014)
2SLS MODELS:						
IV: Stillbirth (*F* = 7.71**)						
Family size	-0.022	-0.221	-0.347	-0.254	-0.337	0.337
	(0.208)	(0.204)	(0.217)	(0.205)	(0.204)	(0.406)
IV: Caesarean section (*F* = 35.91***)						
Family size	0.203	-0.018	-0.029	-0.125	-0.108	-0.282
	(0.104)	(0.094)	(0.093)	(0.092)	(0.090)	(0.169)
IV: Stillbirth and caesarean section (*F* = 22.76***)						
Family size	0.163	-0.057	-0.089	-0.149	-0.150	-0.165
	(0.090)	(0.083)	(0.082)	(0.082)	(0.080)	(0.149)
First stage regressions: [a]						
Stillbirth	0.338**					
	(0.110)					
Caesarean section	-0.900***					
	(0.146)					
P-value for overidentification test	0.360	0.369	0.153	0.561	0.314	0.127
Reduced-form equations:						
Stillbirth	-0.0001	-0.068	-0.107	-0.082	-0.103	0.094
	(0.064)	(0.063)	(0.062)	(0.061)	(0.061)	(0.112)
Caesarean section	-0.177*	0.020	0.032	0.114	0.103	0.240
	(0.085)	(0.083)	(0.082)	(0.081)	(0.082)	(0.149)

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ (two-tailed). Number of observations = 4,448. [a] First stage models include all parental and child controls. All models also control for missing data on log family income, father’s schooling, mother’s schooling, father’s occupation, birthweight, mother’s smoking behavior, mother’s BMI, and mother and father’s age at birth of NCDS child.

Table A1

Summary of the Effect of Family Size on Years of Completed Schooling in Previous Studies

Study	Estimate of family Size	Data	Nationality of sample
Duncan 1967	-0.14 to -0.22[a,d,m]; -0.04 to -0.13[c,d,m]	OCG, 1962	US
Duncan, Featherman, and Duncan 1972	-0.21[a,m]	OCG, 1962	US
Featherman and Hauser 1976	-0.287[m(OCG62)]; -0.202[w(OCG62)]; -0.291[m(OCG73)]; -0.214[w(OCG73)]	OCG, 1962 and 1973, married respondents	US
Hauser and Featherman 1976	-0.19 to -0.26[m,d]	OCG, 1962 and 1973	US
Featherman and Hauser 1978	-0.184 to -0.227[m,d]	OCG, 1973	US
Olneck and Bills 1979	-0.153[m,s,e]	OCG, 1962 and 1973; Kalamazoo Brothers	US
Blake 1981	Negative[f]	Various	US
Datcher 1982	-0.255[a]; NS[b]	PSID	US
Alwin and Thornton 1984	-0.16[a]	Sample of white families in Detroit, Michigan, 1961	US
Blake 1985	Negative[f,m]	OCG, 1962 and 1973, GSS, 1972-1983	US
Hauser and Sewell 1985	Negative[f]	WLS	US
de Graaf 1986	-0.112[s]	1977 Quality of Life Survey	Netherlands
Hill and Duncan 1987	-0.19[m]; -0.14[w]	PSID	US
Teachman 1987	-0.112[a,m]; -0.119[a,w]	NLS	US
Krein and Beller 1988	-0.19[a,m]; -0.13[b,m]; -0.14[b,w]	NLS	US
Blake 1989	-0.199 to -0.240[a,m]; -0.171 to -0.193[a,w]	OCG, 1962 and 1973, GSS, 1972-1986	US
Mare and Tzeng 1989	-0.168[m]	OCG, 1973	US
Shavit and Pierce 1991	Negative (Jews)[f,m]; NS (Arab men)	Representative Israeli Jewish/Arab sample	Israel
de Graaf and Huinink 1992	-0.066 to -0.153[d,s]	German Life History Study	Germany
Butcher and Case 1994	-0.507[a,m,e]; -0.186[a,w,e]	PSID	US
Hauser and Kuo 1998	Negative [f,w]	OCG, 1973; SIPP, 1986/1988; NSFH, 1989	US
Sandefur and Wells 1999	-0.10[s]	NLSY	US
Conley 2000	-0.10	PSID	US
Case, Lin, and McLanahan 2001	-0.057	PSID	US
Conley 2001	-0.124	PSID	US
Evans, Kelley, and Wanner 2001	-0.12	International Social Science Surveys	Australia
Sieben, Huinink, and de Graaf	-0.081 to -0.236 (FRG)[s];	Various data sets	(Former)

2001	-0.089 to -0.178 (GDR)[s]; -0.029 to -0.03 (Netherlands)[s]		Federal Republic of Germany; (Former) German Democratic Republic; Netherlands
Plug and Vijverberg 2003	-0.152	WLS	US

Notes: [a] Whites, [b] Blacks, [c] Non-whites, [m] Men, [w] Women, [s] Sibling model, [d] Estimate varies by cohort, [e] Includes non-linear effect of family size, [f] Estimate not presented in metric scale. NS = No significant effect. Estimates are shown for models controlling the maximum number of other socioeconomic, family, and demographic variables. Results apply to both men and women unless stated otherwise. Data sources: OCG = Occupational Change in a Generation, PSID = Panel Study of Income Dynamics, WLS = Wisconsin Longitudinal Study, GSS = General Social Survey, NLS = National Longitudinal Study, NLSY = National Longitudinal Survey of Youth, GSOEP = German Socioeconomic Panel, NSFH = National Survey of Families and Households, SIPP = Survey of Income and Program Participation.

Table A2
Linear Probability Models of Stillbirth and Caesarean Section

	Stillbirth	Caesarean section
Log family income	0.0005	0.003
	(0.003)	(0.002)
Father's years of schooling	-0.005	0.0003
	(0.002)	(0.002)
Mother's years of schooling	-0.0002	0.004
	(0.003)	(0.002)
Father's occupation		
Professional	Ref.	Ref.
Managerial and Technical	-0.006	-0.008
	(0.022)	(0.016)
Skilled non-manual	0.004	-0.011
	(0.023)	(0.017)
Skilled manual	0.002	-0.004
	(0.021)	(0.016)
Partly skilled	0.012	0.005
	(0.023)	(0.017)
Unskilled	0.043	-0.006
	(0.024)	(0.018)
Single-parent household	-0.004	0.001
	(0.028)	(0.021)
Induced abortion	0.046***	0.014
	(0.010)	(0.008)
Mother smoked before pregnancy with NCDS child	-0.0002	-0.0008
	(0.002)	(0.001)
Mother's BMI at birth of NCDS child	0.002	0.001
	(0.001)	(0.0007)
Mother's age at birth of NCDS child	0.002*	0.003***
	(0.0008)	(0.0006)
Father's age at birth of NCDS child	0.002*	-0.0004
	(0.008)	(0.0006)
Constant	-0.060	-0.135***
	(0.039)	(0.040)
Adj. R^2	0.020	0.013

Notes: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ (two-tailed). Number of observations = 4,448. Models also include dummies for missing data on log family income, father's schooling, mother's schooling, father's occupation, mother's BMI, and father and mother's age at birth of NCDS child.