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The Child Quantity-Quality Trade-Off during the Industrial Revolution in England*

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Abstract We take Gary Becker's child quantity-quality trade-off hypothesis to the historical record, investigating the causal link from family size to the literacy status of offspring using data from Anglican parish registers, c. 1700–1830. Extraordinarily for historical data, the parish records enable us to control for parental literacy, longevity and social class, as well as sex and birth order of offspring. In a world without modern contraception and among the couples whose children were not prenuptially conceived we are able to explore a novel source of exogenous variation in family size: marital fecundability as measured by the time interval from the marriage to the first birth. Consistent with previous findings among historical populations, we document a large and significantly negative effect of family size on children's literacy.

Keywords: Child Quantity-Quality Trade-Off, Demographic Transition, Industrial Revolution, Instrumental Variable Analysis, Human Capital Formation

JEL Classification Codes J13, N3, O10.

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1 Introduction

In recent years, Gary Becker's child quantity-quality trade-off hypothesis has undergone substantial econometric examination.[1] While these investigations build almost exclusively on contemporary data, recent interest in long-term economic and demographic developments has made it relevant to explore the Beckarian trade-off hypothesis using historical statistics. In particular, England's industrial revolution and subsequent growth experience has inspired a large and growing theoretical literature known as *Unified Growth Theory*. Building on seminal work by Galor and Weil (2000) and Hansen and Prescott (2002), several attempts have been made to try to pinpoint the factors that ultimately triggered the transition of western-world countries from thousands of years of *Malthusian* stagnation into their current era of sustained economic growth (Galor, 2011). The key theoretical mechanism to explain this transition to riches, inspired by Becker's trade-off hypothesis, is that parents, in response to economic incentives, started to invest in the human capital of their offspring – an investment made possible by a reduction in the number of births.[2]

The present study is the first to examine the existence of a child quantity-quality trade-off in England during the industrial revolution. Since public schooling was not yet widespread, we investigate the causal link from family size to the literacy status of the family's offspring using raw, hitherto unused family-level data derived from Anglican parish registers (English church book records). The data enable us to explore variation across 1,294 individuals coming from 589 families who lived in England in the 'long' eighteenth century, c. 1700-1830. In a world without modern contraception and among the couples whose children were not prenuptially conceived we are able to explore a new source of exogenous variation in family size: marital fecundability as measured by the time interval from the marriage to the first-born child. Extraordinarily for historical demographic statistics, the data allow us to control for a variety of family characteristics,

[1]See Angrist et al. (2010); Black et al. (2005); Caceres (2006); Li et al. (2008); Rosenzweig and Wolpin (1980); Rosenzweig and Zhang (2009).

[2]Among the most recent contributions in this area are Croix and Licandro (2007) and O'Rourke et al. (2010).

including parental literacy, longevity, and social class, as well as sex and birth order of offspring. We are able to document a large and statistically significant negative effect from quantity to quality: each additional child decreased the chances of finding literacy among all family siblings by more than eight percentage points, thus lending strong support to the Beckerian trade-off hypothesis. The results provide an underpinning for one of the fundamental theoretical pieces of Unified Growth Theory, and are in line with recent findings by Becker et al. (2010), who report a significant trade-off effect using sex ratio as an instrument for fertility and county-level data from Prussia in 1849.

The paper is organized as follows. First, we provide a detailed description of the data used for the analysis (Section 2). We explain the main features of historical family planning and how these enable us to explore fecundability as a source of exogenous variation in family size (Section 3). And we give details on how the data sample is limited (Section 4). Next, we describe how the instrumental variable is constructed, and we discuss the exclusion restriction (Section 5). We then perform the analysis and describe the results (Section 6). Finally, we conclude (Section 7).

2 Data Description

The data used has been collected since the 1960's from Anglican Church book registers by the *Cambridge Group for History of Population and Social Structure* (Wrigley et al., 1997). It offers an extraordinary insight into the demographic life-history of individuals and families, built up from records of their birth, marriage, and death dates. The full data covers 26 parish registers scattered across England in a way that makes them demographically representative of the entire country (*ibid.*). While the entire data set spans between 1541 and 1871, the information permitting us to conduct the quantity-quality trade-off analysis mainly falls within the period 1700-1830 and includes a total of 15 parish registers.

The Cambridge Group has used the church book data to reconstruct families based on the demographic observations of family members. In addition to the dates of events, the data not only enables a count of the number of offspring of all couples in the sample. It also details (in some but not all cases) a person's age, occupation, and literacy status. A person's literacy status is derived from his or her wedding certificate on the assumption that a signature on the certificate indicates that the person was literate, while a mark indicates illiteracy (Schofield, 1973). Obtaining literacy in historical England was by no means free of charge. Sunday schools and most other teaching institutions demanded a fee, and only a very limited number of genuinely free places were available. Surveys done for early nineteenth-century England show that, even in the case of free schools, school attendance dropped when employment was available. The ability to read and write was, therefore, in direct competition with other goods for cash expenditure (*ibid.*).

Table 1 offers a more exact account of the statistics obtainable from the church book records, as well as information that can plausibly be inferred from the records, such as someone's longevity, social status, and number of surviving offspring. Asterisks in the table signify variables that were deduced, either by us or by the Cambridge Group. Every record in the *family reconstitution* is built up around a marriage, and Table 1 offers a representative example containing the recorded information of the marriage between Joseph Chester and Mary Smalley. The marriage took place on 16 May 1811 in Shepshed, Leicestershire. Shepshed is characterized by Schofield (2005) as an 'industrial' location. The label 'industrial' is given to parishes where 30 percent or more of all males over 25 years of age observed in the church book are recorded as being engaged in occupations that are categorized as industrial (smiths, brick makers, tailors etc). By similar reasoning, other parishes are labelled 'agricultural', 'retail and handicraft' and 'other', the latter being a mix of the three others.

The record also states that husband Joseph was born (baptised) on 16 April 1785, and that he died (was buried) on 16 October 1844. As was common practise at the time, the church typically took down baptism and burial dates rather than birth and death dates. Birth and death dates, when available, are the default options. In almost all cases in our sample, however, only baptism and burial dates are available. The fact that the records report baptism and burial dates rather than birth and death dates is not a serious problem

Table 1: Family-Level Data: Marriage Number 599 in Shepshed (Observed and Inferred)

Marriage number	**Date**	**Parish name**	**Parish type**	**TTFB**	**TTFB (age adj.)**	**Fertility**	**Age> 5**
559	16 May 1811	Shepshed	Industrial	0.87	-0.80	8	8
Spouse's name	**Birth**	**Death**	**Age**	**Marriage age**	**Literacy**	**Occupation**	**Social class**
Joseph Chester	16 April 1785	16 Oct 1844	60	26	Literate	Farmer	Manual
Mary Smalley	3 June 1787	25 Sep 1846	59	24	Literate	-	-
Child's name	**Birth**	**Death**	**Age**	**Marriage no**	**Literacy**	**Order**	**Sex**
Mary	27 Mar 1812	-	> 5	1789	Illiterate	1	F
Sarah	24 Dec 1813	-	> 5	1661	Literate	2	F
Catherine	22 Mar 1815	28 Sep 1826	12	-	-	3	F
Maria	16 Aug 1817	-	> 5	2165	Literate	4	F
Joseph	23 Oct 1819	-	> 5	-	-	5	M
William	2 Apr 1823	-	> 5	-	-	6	M
Fanny	27 Jul 1826	24 Jan 1844	18	-	-	7	F
Catherine	11 Apr 1828	-	> 5	-	-	8	F

Source: Cambridge Family Reconstitution Data (Wrigley *et al.* 1997).

for our analysis. For obvious reasons people were buried shortly after their death, in most cases within three days (Schofield, 1970).[3]

Furthermore, towards the end of the eighteenth century most children were baptised within a month of birth, a number slightly greater than what was observed in previous centuries (Midi Berry and Schofield, 1971). Since 99 percent of the individuals in our sample were baptised after the seventeenth century, this should have no bearing on our analytical results.

In Table 1 we have used Joseph's baptism, burial and marriage dates to approximate his age at death, which was 60 years, and his age at marriage, which was 26 years. The records tell us that Joseph was literate and that at the time of his marriage he was a farmer. In addition to documenting occupation at the time of the marriage, the records sometimes report the husband's occupation at his death or at the birth or death of some of his offspring. Occupation at marriage is the default variable on the assumption that this gives a more precise picture of the families' life-long wealth potential compared to occupations reported later in life. In cases where the data only reports occupation at death, or at the birth or death of offspring, we use the earliest registered occupation as a proxy for occupation at marriage.

Occupational information can be used to approximate a family's wealth status as follows. Firstly, the *History of Work Information System* (HISCO), documented in Leeuwen et al. (2007), gives standardized codes to tens of thousands of occupational titles, which existed between the sixteenth and the twentieth centuries in countries all around the world (England included). Using these codes in combination with the HISCLASS system, documented in Leeuwen and Maas (2011), we are able to map all occupational titles in the data into one of two social classes: *manual* and *non-manual* labourers.[4] Secondly, Clark and Hamilton (2006) have demonstrated, by analysing wealth at death among male testators, that the wealth of manual labourers was significantly lower than that of their

[3]The proportion of burials in Hawkshed, Lancashire, in the late eighteenth century at different intervals after death were as follows: same day, 1%; 1st day, 21%; 2nd day, 50%; 3rd day, 25%; 4th day, 2%; 5th to %7th day, 1% (*ibid.*).

[4]We can observe from cases where we have occupation (and thus social class) recorded more than once, for example at marriage and at death, that the social class mappings are significantly positively correlated.

non-manual counterparts. Putting the HISCLASS and the wealth information together, we thus get a crude proxy for wealth status among those families in the data where the husband's occupation is available. Husband Joseph's occupation (farmer) places him in the group of manual workers, putting his family in the category of less well-off households.

Table 1 also shows that Joseph's wife Mary lived to reach 59; that she married at age 24; and that she was literate. Mary gave birth to six girls and two boys. Three of her children - Mary, Sarah, and Maria - married in their parish of origin. By visiting each of the children's marriage records (family reconstitution numbers 1789, 1661, and 2165 of Shepshed), the records show that daughter Mary was illiterate, while her two sisters Sarah and Maria were both literate. Daughters Catherine and Fanny died in the parish of Shepshed at ages 12 and 18, respectively, before getting married. The three remaining children – Joseph, William and a *second* daughter by the name of Catherine - have no death or burial dates registered in the parish of Shepshed. This is evidence that they migrated to a different parish location where we are unable to observe them (Souden, 1984). The average migration rate by sample family offspring is close to 50 percent. This relatively high migration rate is consistent with the substantial relocation from rural to urban areas, which took place over the eighteenth century (Allen, 2000).[5]

Given their limited influence on the family budget, we exclude children who died before reaching age five when counting family sibship size.[6] This raises the issue of how to tell if *migrating* children – those whose death date we cannot observe – survived to age five. Children would normally remain with their parents until age five. So in the absence of later church book observations of the child, such as marriage date, we need to make sure is that its parents did not leave the parish before the child turned five. This is done by looking for subsequent births or deaths (within age five) of a sibling or a parent within five years of the birth of the child in question. It is easy to confirm this way that all the

[5]From 1700 to 1800 the share of England's population living in urban areas doubled (*ibid.*, Table 2).
[6]This has no significant bearings on the findings reported below.

children of the Chester family described in Table 1 survived to age five. We can also tell that, in the baseline sample used below, 85 percent of all children surpassed age five.[7]

3 Historical Family Planning

Some knowledge about family planning in historical England is required to endorse the instrumental variable used in the analysis below. A key feature of historical family planning in England is that child-birth outside of marriage was seen as a highly immoral act in the eyes of the Church. Indeed, this was an act whose resulting social illegitimacy eventually had a strong influence on the social status and mortality of these children, as documented by (Stone, 1977). While *prenuptially conceived* births, i.e. children conceived *before* marriage but born within marriage, was a rather common feature of English population history, the desire to avoid pre-marriage deliveries effectively meant that births in the majority of cases came after marriage.[8]

The absence of modern contraceptives furthermore meant that within-marriage births were subject to limited control. Abstinence from intercourse, *coitus interruptus*, and extended breast-feeding were the main possibilities of controlling fertility after the onset of marriage (Wrigley et al., 1997). Evidence suggests, however, that these possibilities were rarely exercised. It is well documented that historical England was a society characterised by *natural fertility*. The concept of natural fertility was defined in Henry (1961) as the absence of deliberate birth-control within marriage. Coale and co-authors used this to develop a formal method for estimating a society's degree of natural fertility by comparing its age-specific marital fertility rates to those of a natural fertility society.[9] Wilson (1984) later used that method to show, based on the data used in the present study, that historical England was indeed characterised by natural fertility.

[7] There were two children - one in the baseline sample and one in a bigger sample used for the Heckit analysis below – whose survival information we were unable to infer. Both these children were deemed to have survived their fifth birthday.

[8] It has been estimated that in the late eighteenth and early nineteenth century roughly six percent of all births were illegitimate (Wrigley et al., 1997).

[9] Coale (1971); Coale and Trussell (1974); Coale and Trussell (1975); and Coale and Trussel (1978).

Figure 1: Mary Chester's Reproduction History

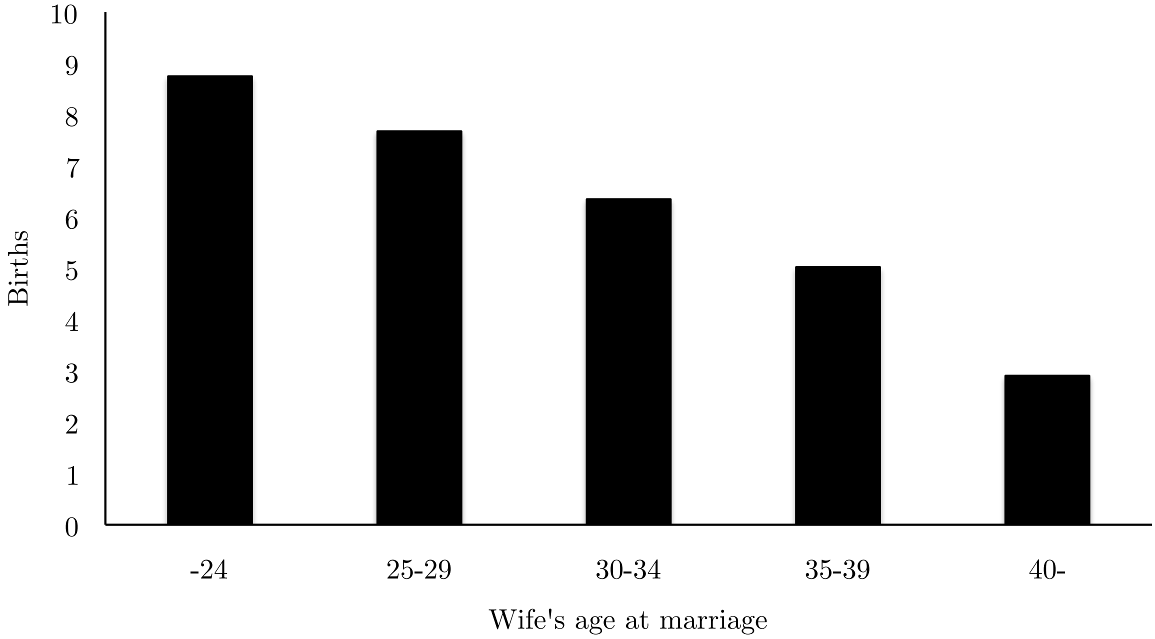
Note: numbers are Mary's age at the time of birth

The lack of within-marriage birth control meant that marital births normally continued up until the end of the wife's reproductive period (usually between ages 40 and 50). Figure 1 illustrates the point, showing the births of Mary Smalley (from Table 1) plotted against time. In principle, the absence of birth control should result in a linear relation between births. This is almost the case for Mary, except for two shifts in the curve caused by extended birth spaces between births five and six and six and seven. Such extensions were often produced by miscarriages (Wrigley et al., 1997). The fact that historical England was characterized by natural fertility effectively meant that the main means of birth control was delayed marriage, a point already stressed centuries ago by Malthus (1798). Figure 2 illustrates this point, showing the average number of births by the wife's age at marriage (using the baseline data sample described further below).[10]

The fact that couples were able to target their family size by the timing of their marriage did not necessarily mean that they would eventually meet their goal in terms of number of offspring. Child mortality would influence the target number of surviving

[10]Boberg-Fazlic et al. (2011) has demonstrated on the same data that middle-class families (gentry, merchants or other professionals) gave birth to more offspring than their less well-off counterparts (husbandmen, labourers, and servants) precisely because richer husbands married younger brides.

Figure 2: Average Number of Births by the Wife's Age at Marriage



offspring, and the early death of a spouse would effectively end births before the target was reached. Since the death of a spouse would likely also have independent effects on the human capital of the offspring, we exclude families where either spouse died before the wife completed her reproductive age. That is, we include in the analysis below only so-called *completed* marriages (Wrigley et al., 1997, p. 359).[11]

Within completed marriages a vital factor influencing family size was the couples' fecundability, defined as the probability of the wife conceiving in the course of a single monthly cycle (subject to the couples having unprotected intercourse). In a natural fertility society, such as England's, marital fecundability would more or less entirely determine a couple's fertility. Couples of high and low fecundability would thus be equally exposed to the risk of ending up with an off-target family size.[12] This means that the differences in marital fecundability can be explored as a source of exogenous variation in family size.

That brings us straight to the matter of how to actually *measure* marital fecundability among the couples in the data. Demographers have argued that, among couples where

[11]Later sensitivity analysis shows that including also non-completed marriages has no qualitative bearings on the results.

[12]In a world of perfect birth control, on the other hand, it is clear that only couples of low fecundability would risk ending up with a below-target number of offspring.

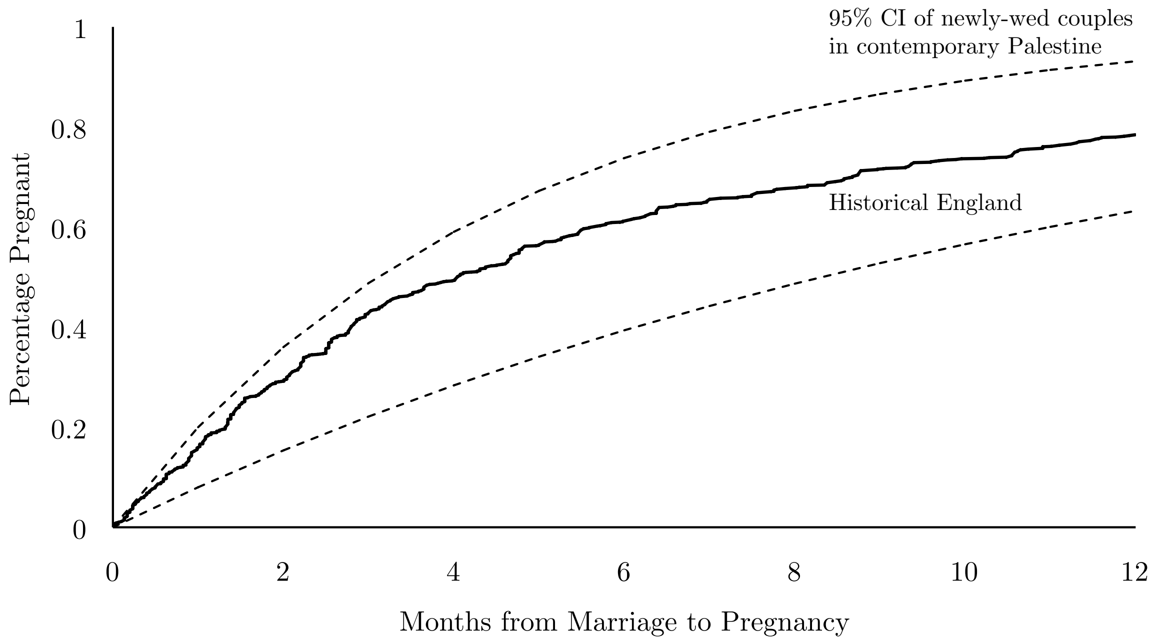
marriage marks the onset of unprotected sex, marital fecundability can be estimated by the time interval from the marriage of a couple to their first birth (see for example Wrigley et al. 1997, pp. 465). But did marriage mark the onset of unprotected sex in historical England? Certainly not for everyone: prenuptially conceived births were a common feature of English population, with roughly 40 percent of all births taking place within nine months of marriage (*ibid.*). If, however, we exclude these families from the data, then a strong case can be made that marriage, among the remaining families, marks the starting point of trying to conceive a child.[13]

To substantiate this claim, we now proceed to compare the time from marriage to first birth among the couples of our sample to couples from a population in which we know that the wedding date marks the onset of unprotected sex, namely among newlywed couples in agricultural villages in Palestine, studied by Issa et al. (2010). There are three main reasons why the study of Palestinian couples is particularly well suited for a comparison with the English data. First, pre-marital sex is a cultural taboo in the contemporary Palestinian community, and the authors of the study found no evidence of pre-marital pregnancies, or even co-habitation, among the observed couples. Second, the Palestinian couples started unprotected sexual intercourse *at the date* of marriage in order to conceive their first child. Thereafter, the couples observed were recorded to have frequent intercourse until pregnancy was achieved, with 16 percent having intercourse between one and six times per week, and 74 percent having intercourse more than seven times weekly (11 percent refused to answer). Finally, by contrast to other studies of Western-world fecundability, the study on Palestine includes information on unprotected intercourse not leading to pregnancy, making it directly comparable with our couples.

Overall, their cumulative fecundability was a 12 percent chance of conceiving after one month; 64 percent after six months; and 76 percent after 12 months. By comparison, the cumulative fecundability in our sample was 16, 61 and 78 percent, respectively. The former numbers report fecundability among the Palestinian wives whose educational attainments were less than 10 years of schooling (*ibid.*, Table 1), comparable to those of our sample.

[13]Later sensitivity analysis will demonstrate that results are not sensitive to the exclusion of families of prenuptially conceived births.

Figure 3: Cumulative Fecundity: Contemporary Palestine and Historical England



In order to give a more visual impression, the dotted lines of Figure 3 envelop the 95-percent confidence interval of cumulative fecundability of the Palestine couples. The solid line illustrates the cumulative fecundability of our baseline sample. Since the Cambridge records measures the interval from marriage to first birth, and not to first pregnancy, we have subtracted the time difference between the time of conceiving and the time of birth (i.e. a time span of nine months). Furthermore, as mentioned above, we have excluded families with prenuptially conceived first-born children. It is immediately clear that the couples of the Cambridge data fit well within the boundaries of the Palestinian fecundability patterns. Taken together, the evidence presented in Figure 3 not only seems to suggest that marriage marks the onset of unprotected sex among those couples of the Cambridge data where the first delivery appears more than nine months into the marriage. Since we know that the Palestinians did not postpone their pregnancies after marriage, Figure 3 also demonstrates, importantly, that our historical couples do not display deliberate delaying behaviour. This suggests that the time interval between the marriages to the first deliveries can be used as a proxy for marital fecundability among the couples observed in the data.

4 Data Limitation

The Cambridge data contains a total of 7,504 individuals with known literacy status, birth information, and parental marriage dates. These individuals come from a total of 4,121 families. However, as indicated in the previous sections, we wish to restrict the set of families in the sample to include only completed marriages with no prenuptially conceived first-borns.

In order to do this, we need to know the wife's birth and death dates as well as the husband's death date. We also require knowledge of the husband's birth date since we would like to control for parental health, for which we will use the longevity of the spouses as a proxy. Since missing birth or death dates indicates migration, knowledge of the husband's birth date also ensures that he did not bring unobserved children from a previous marriage along coming from a parish outside the sample. By including only completed marriages in the sample, and by requiring in addition that we know the birth dates of husbands, the total number of individuals drops to 2,172, coming from a total of 955 families. In later robustness analyses, we relax some of these assumptions to investigate how robust our conclusions are towards using larger (but less appropriate) samples.

Turning to the issue of prenuptially conceived births, roughly 40 percent of the 955 completed marriages present in the sample gave birth to their first child *within* nine months of the marriage.[14] It is indeed questionable whether the time from marriage to the first birth offers any insight into the fecundability of couples that gave birth to children born within marriage but conceived before. For that reason, we exclude the affected families from the baseline analysis below, but we re-introduce them later for robustness purposes. In the meantime, excluding them from the sample leaves us with 1.294 individuals from a total of 589 families.

Table 2 reports the summary statistics of the baseline sample. Around 58 percent of all individuals in the sample were literate. The average birth rate among the families included

[14] Some of these, of course, could be premature births, the prevalence of which among modern populations is up to 15 percent of all births (Slattery and Morrison, 2002).

Table 2: Summary Statistics

	Obs (1)	Mean (2)	StDev (3)	Min (4)	Median (5)	Max (6)
Offspring Literate	1294	0.58	0.49	0	1	1
Sibship Size	1294	6.96	2.94	1	7	21
Sibship Size (> 5 years)	1294	5.99	2.54	1	6	16
TTFB	1294	1.51	1.14	0.75	1.09	9.92
Male Sex	1294	0.41	0.49	0	0	1
Husband's Longevity	1294	72.34	9.69	40.41	72.69	96.61
Wife's Longevity	1294	71.74	10.22	50.10	72.45	102.49
Husband Literate	921	0.62	0.49	0	1	1
Wife Literate	892	0.35	0.48	0	0	1
Husband Manual Occupation	845	0.76	0.43	0	1	1
Wife's Age at Marriage	1294	24.87	4.45	15.38	24.12	42.21
Agricultural Parish	1294	0.30	0.46	0	0	1
Retail Parish	1294	0.11	0.31	0	0	1
Industrial Parish	1294	0.31	0.46	0	0	1
Other Parish	1294	0.28	0.45	0	0	1

Source: Cambridge Family Reconstitution Data (Wrigley *et al.* 1997).

was seven children, out of which six made it to age five. The average time from marriage to the first birth was roughly one and a half years. This is four months longer than the median time interval (one year and one month), capturing the fact that the distribution is skewed to the right. Table 2 also tells us that there were 41 percent males among the surviving offspring. The reason that this number is below the share of men in the population (i.e. around 50 percent) is that men were more likely than women to emigrate for marriage (Souden, 1984). The data tells us that the average longevity of wives conditional on surviving to age 50 was 71.7 years, while the average longevity of husbands conditional on surviving until their wives turned 50 years of age was 72.3 years. As regards the literacy status of spouses, this is unknown for some but not all of the individuals in the sample. We know the literacy status of 892 wives, 35 percent of whom were literate. Similarly, the literacy status is available for 921 husbands, out of whom 62 percent were literate. In 845 of the 1,294 cases we know the occupation of husbands, and roughly 40 percent of these are classified as manual workers, according to the HISCLASS occupation classification system described above. Finally, around 30 percent of the individuals in the sample lived in parishes dominated by agricultural activities; slightly more (31 percent) lived in parishes dominated by industrial activities; 11 percent lived in parishes characterised by retail and handicraft, while the rest (28 percent) lived in parishes where economic activities were mixed.

5 Exogeneity of the time to first birth

Is the time interval from the marriage to the first birth a valid instrument for family size? The question of whether the exclusion restriction is satisfied translates into a question of whether the time interval to first birth – henceforth TTFB – is indeed exogenous to the couples in the sample, and whether it is correlated with any omitted variables which would affect the literacy of their offspring.

The first concern is the possible association between parental age and fecundability. The fecundability of women starts to fall around the mid-30s (see Baird et al. (2005), Larsen and Vaupel (1993) and van Noord-Zaadstra et al. (1991)). If we do not correct for this, there is a risk that our instrument captures the effect of marriage age on fertility rather than biological circumstances that are exogenous to the couple. In order to account for any variation in female fertility across age groups we proceed to compute an individual, age-adjusted measure of the TTFB. Explicitly, we calculate the age-specific mean of women grouped into five-year-interval marriage cohorts and then subtract from that the time interval from marriage to first birth of each couple in the sample. To illustrate this for the case of the Chester family described in Table 1 above, their time span from marriage to first birth was 0.87 years. From this number we subtract the age-specific mean of Mary's marriage cohort (ages 20-25) which was 1.67 years. This results in an age-adjusted TTFB of -0.80 years, indicating a relatively high marital fecundability of the Chester couple.[15]

The second concern is the possitibility of omitted variable bias. One potential problem is that the data does not offer any direct information about parental income and health. What would be the effect of excluding health and income from the regression? TTFB

[15] We recalculate the age-adjusted TTFB for each sample used below. The results are robust toward the adjustment of the TTFB.

may be negatively correlated with parental health status, which in turn may be positively correlated with parental income. Higher income, and thus better health, would lead to a shorter TTFB and thus *ceteris paribus* to more children. On the other hand, parental health and income may have *direct* effects on the literacy of children: higher income affords more education, and healthy parents are more likely to be able to care for their offspring. Hence, higher income and better health would increase the chances of finding literacy among the offspring. Thus, if health affects TTFB, excluding health and income from the regression would bias the estimated trade-off effect upwards. This means that if we were to exclude health from the regressions, the true effect would likely be even stronger than the observed effect.

We are able, however, to proxy for income and health using information derived from the data. In order to proxy for income, we subdivide families depending on whether the father's occupation is manual or non-manual, because we know that that manual families were less affluent then non-manual ones (as described above). We proxy for parental health by controlling for longevity of the wife and the husband. Not only will parental longevities capture family-specific genetic effects. They will also reflect the sanitary circumstances and the disease environment surrounding the household.

6 Analysis and Results

We now advance to estimate the effect of sibship size on individual literacy using OLS and 2SLS regression analyses on the sample of the 1,294 individuals described in Table 2 above.

The OLS model is given by the following equation:

$$\text{literacy} = \alpha_0 + \alpha_1 \text{sibshipsize} + \alpha_2' Z + \varepsilon,$$

where Z is a vector of covariates, and ε is an error term. Covariates comprise sex of offspring; parental literacy; parental longevity; occupational status of the husband (manual or non-manual labour); a linear time trend (centuries from year 1580 to the birth date of each individual); the parish type by occupational structure; and finally dummy variables for birth order and for missing information regarding parental literacy as well as occupation of the husband. Birth order effects include single orders from one up to nine and then 10+. We use the same covariates in both the OLS and the 2SLS regression analyses.

As has been recognized in the existing literature, the OLS estimate may be biased. That is, an observed negative association between sibship size and literacy may not have a causal interpretation (e.g. Angrist et al. (2010)). If, for example, literacy depends negatively on fertility, and fertility in turn depends negatively on literacy, then the OLS estimate of α_1 will be downward biased. If literacy and fertility, on the other hand, are both positively correlated with an omitted variable, then the estimate of α_1 will be upward biased. As in the existing literature we attempt to tackle these potential problems of endogeneity by use of 2SLS analysis. Specifically, the first step predicts sibship size using the age-adjusted TTFB (measured in years), as well as covariates. The second step then predicts literacy using the equation described above. The first-stage regression equation of the 2SLS analysis hence reads

$$\text{sibshipsize} = \beta_0 + \beta_1 X + \beta_2' Z + \nu,$$

where X is the instrumental variable, Z the covariates, and ν is an error term.

The estimation results of the OLS and 2SLS analyses are reported in Table 3. Dummy-estimates for birth order, prenuptially conceived births, as well as missing information, are all excluded from the table. We report robust standard errors clustered by family in the table.

Beginning with the OLS results (Column 1), the conditional correlation between sibship size and literacy is negative. Each additional sibling has a partial correlation with the probability of finding literacy among all family siblings of 1.4 percentage points. This is a fairly modest trade-off effect, which is only borderline statistically significant (p=0.11). As discussed above, however, the effect may not have a causal interpretation. Turning

Table 3: Regression Results: Baseline Sample

Sibship Size (> 5 Years)	-0.014		-0.083***
	(0.008)		(0.026)
TTFB (age adj.)		-0.497***	
		(0.054)	
Male	0.102***	-0.001	0.100***
	(0.026)	(0.109)	(0.027)
Wife Literate	0.247***	-0.173	0.229***
	(0.044)	(0.278)	(0.049)
Husband Literate	0.220***	0.559**	0.261***
	(0.045)	(0.264)	(0.050)
Husband Manual Occupation	-0.131***	0.387	-0.107**
	(0.046)	(0.247)	(0.052)
Wife's Age at Marriage	-0.003	-0.208***	-0.017***
	(0.004)	(0.021)	(0.007)
Husband's Longevity	-0.002	-0.004	-0.003
	(0.002)	(0.008)	(0.002)
Wife's Longevity	0.003*	0.022**	0.005**
	(0.002)	(0.011)	(0.002)
Centuries Since 1580	0.000	0.003***	0.000*
	(0.000)	(0.001)	(0.000)
Retail Parish	0.071	-1.005***	0.011
	(0.055)	(0.302)	(0.061)
Industrial Parish	-0.044	-0.141	-0.044
	(0.046)	(0.256)	(0.050)
Other Parish	-0.096*	-0.361	-0.109*
	(0.052)	(0.273)	(0.056)
Constant	0.726***	10.765***	1.464***
	(0.236)	(1.218)	(0.355)
N	1294	1294	1294
Clusters	589	589	589
R^2 (adjusted)	0.171	0.436	0.093
F (Kleibergen-Paap)			84.157

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

to the estimates of the covariates, these are all fully in line with the *a priori*: Males are more likely to be literate than females (10.2 percentage points). Children of literate parents are more likely to be literate themselves (24.7 percentage points in the case of a literate mother; 22.0 percentage points in the case of a literate father). If both parents are literate, therefore, that raises the chances of literacy among their offspring by nearly fifty percentage points. Children of fathers engaging in manual work are less likely to be literate (13.1 percentage points) compared to those whose fathers do non-manual work (suggesting that the children of the rich are more often literate than those of the poor). We can also see that long-lived mothers are more likely to have literate children (0.3 percentage points for each additional year of life). Interestingly, there is no effect on offspring literacy of increased longevity of husbands. Finally, the time trend is insignificant (p=0.34), and the estimate is very close to zero, meaning that chances of finding literacy among offspring do not increase independently over time.

Using our age-adjusted instrument with the ivreg2 module for Stata (Baum et al., 2007b), it follows from the first-stage regression analysis (Column 2 of Table 3) that one additional year above the age-specific mean birth-period means an average decrease of roughly one half surviving offspring. This effect is significant at the one-percent level. The second-stage estimate of sibship size on literacy (Column 3) supports the finding of a trade-off from the OLS analysis. Yet, not only is the effect statistically significant at the one-percent level. It is almost six times bigger than the OLS estimate. That is, each additional sibling reduces the chances of literacy among all family siblings by 8.3 percentage points. The *GMM distance* test implemented in ivreg2 rejects exogeneity of surviving sibship size (p = 0.0032) (see Baum et al., 2007a). Note that the Wald F-statistic of 84.3, based on the Kleibergen-Paap rk statistic (Kleibergen and Paap, 2006), is well above the critical value of 10, suggesting that we are not facing a problem of a weak instrument (Baum et al., 2007a).

The sample used for the baseline analysis above fulfils a number of rather strict criteria. It would be interesting to see, therefore, if by relaxing some of these criteria we are able to draw conclusions similar to those of the baseline regression for a bigger group of individuals. So we now proceed to run four sensitivity regression analyses, the results of which are reported in Table 4.

Compared to the baseline findings (repeated in Column 1 for completeness) we begin by including families in which marriage did *not* mark the onset of unprotected sex, namely those whose first child was born within nine months of marriage. While the TTFB among these families arguably has little to say about the biological aspects of the couples' fecundability, it does indicate, as argued by Wrigley et al. (1997, p. 364), that an early birth after marriage in a family with a prenuptially conceived first-born is a sign of a large appetite for sex between the couple. That appetite, in turn, would increase the wife's chances of getting pregnant also within marriage. The inclusion of families of prenuptially conceived first-borns increases the sample-size to 2,172 individuals coming from a total of 955 families (Column 2). The control variables are the same as in the baseline regression, except for the fact that we now include a dummy for families of prenuptially conceived births. While the estimate is slightly smaller than in the baseline regression – a 7.4 percent decrease in chances of literacy for each additional child surviving to age five – it is still significant at the 1-percent level.

The next step conducted to increase the size of the sample involves relaxing the assumption that sterility sets in when the wife reaches the age of 50. Since women rarely give birth after the age of 40 years (less than 15 percent of the children in the baseline sample were born after their mother reached her 40th birthday), we will now require only that women remain alive to the age of 40 instead of the age of 50. Moreover, we will also no longer demand that the husband remains alive until the wife completes her reproductive period. We thus no longer require marriages to be *completed*. This gains another 493 observations, leaving us with 2.665 individuals coming from a total of 1,230 families (Column 3). The control variables are still the same as in the baseline regression. Note that since incomplete marriages by construction are negatively correlated with family size, and presumably positively correlated with factors that are negatively correlated with literacy, we would expect the estimate to get numerically closer to zero. Indeed, we

Table 4: Robustness Results: Extended Samples

Sibship Size (> 5 Years)	-0.083***	-0.074***	-0.069***	-0.069***	-0.053**
	(0.026)	(0.025)	(0.024)	(0.024)	(0.024)
Male	0.100***	0.108***	0.120***	0.120***	0.127***
	(0.027)	(0.021)	(0.019)	(0.019)	(0.016)
Wife Literate	0.229***	0.241***	0.226***	0.225***	0.235***
	(0.049)	(0.036)	(0.032)	(0.032)	(0.028)
Husband Literate	0.261***	0.236***	0.224***	0.224***	0.227***
	(0.050)	(0.037)	(0.033)	(0.033)	(0.028)
Husband Manual Occupation	-0.107**	-0.122***	-0.126***	-0.126***	-0.152***
	(0.052)	(0.040)	(0.036)	(0.036)	(0.029)
Wife's Age at Marriage	-0.017***	-0.012*	-0.010*	-0.010*	-0.008
	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)
Husband's Longevity	-0.003	-0.001	0.000		
	(0.002)	(0.001)	(0.001)		
Wife's Longevity	0.005**	0.005***	0.005***	0.005***	0.005***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Centuries Since 1580	0.000*	0.000**	0.000**	0.000**	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Retail Parish	0.011	-0.015	-0.015	-0.017	-0.013
	(0.061)	(0.050)	(0.047)	(0.047)	(0.037)
Industrial Parish	-0.044	-0.104***	-0.095***	-0.094***	-0.090***
	(0.050)	(0.039)	(0.035)	(0.034)	(0.029)
Other Parish	-0.109*	-0.127***	-0.117***	-0.115***	-0.081***
	(0.056)	(0.042)	(0.037)	(0.037)	(0.031)
First Child Prenuptially Conceived		0.037	0.026	0.026	0.013
		(0.032)	(0.028)	(0.028)	(0.024)
Constant	1.464***	1.193***	1.037***	1.060***	0.913***
	(0.355)	(0.322)	(0.265)	(0.279)	(0.259)
N	1294	2172	2665	2665	3654
Clusters	589	955	1230	1230	1785
R^2 (adjusted)	0.093	0.106	0.118	0.118	0.129
F (Kleibergen-Paap)	84.157	83.150	99.537	98.873	81.882

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

now find a statistically significant 6.9 percent decrease in changes of finding literacy for each additional child surviving to age five.

In order to increase the sample even further, we now proceed to relax the demand for knowledge about the husband's age at death, thus introducing a risk of including families in the sample with unobserved children (i.e. children born outside the parishes included in the sample). Since this implies that we can no longer use the husband's longevity as a control variable, we first re-run the regression from Column 2 (which requires knowledge about the husband's age at death) without controlling for his longevity. As Column 3 shows, this hardly affects the estimate or its significance. We then relax the assumption of knowledge of husband's age at death (Column 4). Compared to the size of the baseline sample, the final step yields nearly three times as many observations: 3,654 individuals coming from a total of 1,785 families. The effect is still significant (this time at the five-percent level) and now amounts to a 5.3 percent decrease in chances of finding literacy for each additional child. Taken together, the robustness analyses show that estimates are rather robust to the inclusion of more individuals and families, even considering the bias introduced from the inclusion of incomplete families.

An important issue, which remains to be explored, is the fact that in the baseline sample above we included only individuals whose literacy status was known. This meant that those who migrated and married in outside of their parish of origin were eliminated from the sample. Were these individuals significantly different from those in the baseline sample analyzed above? In order to find out, we employ the Heckit model to investigate a potential problem of sample selection bias.[16] To this end, we estimate the probability of observing literacy status based on missing birth and death dates using a probit model in the first stage. A missing death date is evidence that individuals migrated to another parish (Souden, 1984). In this case, we are often unable to observe the person's marriage records, and thus his or her literacy status. Similarly, a missing marriage date often means that the individual went on to marry in another parish.

[16] Since we are already using instrumental variables analysis, we use Procedure 17.2 of Wooldridge (2001, p. 568).

Table 5: Heckit Model

	(1) 1st Stage	(2) 2nd Stage	(3) 3rd Stage
Sibship Size (> 5 Years)	0.006		-0.082***
	(0.020)		(0.026)
Missing Marriage Date	4.079***		
	(0.160)		
Missing Death Date	0.648***		
	(0.075)		
Inverse Mills Ratio		-0.132	-0.025
		(0.201)	(0.046)
TTFB (age adj.)		-0.494***	
		(0.054)	
Male	0.138**	-0.012	0.098***
	(0.057)	(0.112)	(0.028)
Wife Literate	0.012	-0.177	0.228***
	(0.124)	(0.277)	(0.049)
Husband Literate	-0.132	0.567**	0.262***
	(0.118)	(0.262)	(0.049)
Husband Manual Occupation	-0.215	0.413*	-0.103**
	(0.137)	(0.247)	(0.052)
Wife's Age at Marriage	0.001	-0.213***	-0.017**
	(0.010)	(0.021)	(0.007)
Husband's Longevity	-0.003	-0.004	-0.003
	(0.004)	(0.008)	(0.002)
Wife's Longevity	-0.008*	0.023**	0.005**
	(0.004)	(0.010)	(0.002)
Centuries Since 1580	-0.004***	0.003***	0.000*
	(0.000)	(0.001)	(0.000)
Retail Parish	0.506***	-1.063***	0.000
	(0.139)	(0.309)	(0.065)
Industrial Parish	0.259**	-0.168	-0.050
	(0.113)	(0.253)	(0.051)
Other Parish	0.040	-0.375	-0.111**
	(0.118)	(0.273)	(0.056)
Constant	-3.740***	11.449***	1.519***
	(0.586)	(1.389)	(0.385)
N	9753	1294	1294
Clusters	1822	589	589
R^2 (adjusted)		0.435	0.094
F (Kleibergen-Paap)			82.886

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

We use the explanatory variables of the 2SLS analysis conducted above to predict if literacy information is missing, but add two dummy variables: one indicating if the marriage date is missing, and one indicating if the death date is missing. Death dates are missing for 4,833 observations; marriage dates are missing for 6,648 observations; while both dates are missing in 3,275 cases. The outcome variable is a dummy capturing whether the literacy status is known. The results of the Heckit analysis are reported in Table 5. This table shows that the dummy variables for missing marriage and death dates are highly significant (both with $p < 0.000$), suggesting that they have great explanatory power over missing literacy information. In the second step it follows that the inverse Mills ratio is highly insignificant, indicating that we do not have a problem of sample selection bias.

7 Concluding Remarks

We have used data collected from Anglican parish registers to test the Beckerian theory of a child quantity-quality trade-off. The data covers a substantial time period, spanning more than 130 years, including the time of England's industrial revolution. The features of historical family planning, and the fact that we are able in the data to identify couples among whom unprotected sex starts after marriage with no apparent delay-behaviour, allow us the use of a novel instrumental variable in the context of child quantity-quality trade-off analysis: namely the exogenous variation in family size that stems from differences in couples' fecundability, as measured by the time interval from the couple's marriage to their first birth.

We find a negative and strongly significant causal effect on individual literacy of within-family size, as measured by the number of siblings who survive to age five. The magnitude of the trade-off – a decrease in the chances of finding literacy among all family offspring for each additional surviving child of more than eight percentage points – implies a substantial decrease in offspring quality among large families, and hence a strong support to Becker's trade-off hypothesis. In particularly, it suggests that families of low fecundability, and hence fewer births than planned, invested some of their windfall resources in human capital of their offspring, thus displaying preference for child quality.

This, therefore, lend support to a key theoretical mechanism of Unified Growth Theory. This theory builds on the notion that parental preferences entail a quantity-quality trade-off of children; a mechanism conducive to the demographic transition and the escape from Malthusian stagnation to sustained growth (Galor and Weil, 2000). Our findings are also supportive of theoretical work by Galor and Moav (2002), who were the first to argue that the quantity-quality trade-off was decisive to economic advancement, not just from the onset of the demographic transition, but throughout human history.

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