THE CHILD QUANTITY-QUALITY TRADE-OFF: EVIDENCE FROM THE POPULATION HISTORY OF ENGLAND

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Abstract. We investigate the linkage from sibship size to individual literacy with the Cambridge Group's demographic (church book) data for historical England. We use exogenous variation in sibship size from parental fecundity and parish-level neonatal mortality to identify the causal mechanism. Our analysis shows that each additional sibling reduces the probability of being literate among all siblings by roughly 10 percentage points. This existence of a historical child quantity-quality trade-off lends strong support to Unified Growth Theory and squares nicely with empirical findings from historical Prussia.

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1. Introduction

This paper offers a first attempt to analyze the child quantity-quality trade-off for historical England. There are at least three reasons why this may be of interest to scholars. First, whereas the trade-off in contemporary economies has received considerable attention (Angrist et al., 2009; Black et al., 2005; Rosenzweig and Zhang, 2009), the historical record is largely ignored. Second, Unified Growth Theory has emphasized the trade-off as a key mechanism in human evolution and long-run development (Galor and Weil, 2000; Galor and Moav, 2002); yet, this mechanism has not been tested empirically for leading historical economies, such as England's. Finally, a considerable share of apprentices in the run up to the Industrial Revolution indicates that English parents were partial towards child quality far earlier than hitherto thought (Leunig et al., 2009; van der Beek, 2010). This all stress the need for empirical inquiry concerning the existence of a parental trade-off between the quantity and quality of children for historical England.

We estimate the causal linkage from family-level sibship size to individual literacy using the Cambridge Group's detailed demographic data for 26 English parishes covering the period 1580 to 1871 (Wrigley et al., 1997). Sibship size is the number of family-level offspring surviving to age five. Literacy information is inferred from the offspring's signatures on wedding certificates. We control for sex, birth order, parental literacy and occupational status of fathers. OLS regression analysis shows a modest quantity-quality trade-off, but the OLS estimate may be biased. We thus supplement the analysis by using exogenous variation in sibship size from parental fecundity and parish-level neonatal mortality. Our instrumental variable regression analysis reveals a much bigger trade-off: each additional sibling reduces the chances of literacy among all family siblings by roughly 10 percentage points. This conclusion lends strong support to Unified Growth Theory. It also squares nicely with empirical findings from historical Prussia (Becker et al., 2009).

2. Data

The main challenge when analyzing the trade-off historically is that formal schooling does not become widespread before the end of the nineteenth century. However, years of schooling is not the only measure of educational attainment available. Another indicator is the ability to read and write—something which can be inferred from signatures on historical marriage certificates: literate spouses put their name on the marriage document, while illiterate spouses simply leave a mark (Clark, 2007). Parish records (church books) thus provide an excellent source of information concerning the literacy of spouses, and hence offers valuable insight into the human capital of a large group of people at the micro level.

Extraordinary work done in recent decades by the Cambridge Group, documented in Wrigley et al. (1997), enables us to analyze the historical linkage from sibship size to literacy from the end of the Early Modern Era through the Industrial Revolution. Each family in the data set has its own *family reconstitution form*, known as FRF. A complete FRF provides not only detailed information on the husband and wife (their birth, death, and marriage dates, as well as literacy information and occupation). It also offers insight regarding their offspring: in addition to sibship size, we know the offspring's sex, birth order, as well as their birth and death dates. Importantly, if the offspring later engages in marriage, then a complete FRF will link to the FRF of each child; that, in turn, will direct us to the wedding certificate, and thus literacy information, of the offspring. Altogether, this makes possible an empirical analysis of the causal effect of someone's sibship size (quantity) on that someone's literacy (quality).

3. Methodology

Standard OLS estimates of the trade-off may be biased. Problems of endogeneity may arise from omitted variable bias, and from simultaneity in parental decisions regarding quantity and quality. Related studies tackle these issues by means of exogenous variation in sibship size. Traditional instruments include the occurrence of twin births and same-sex children. In the latter case, preference for mixed-sex siblings appear to raise fertility until the desired ratio is met; typically, families partial towards male births increase sibship sizes beyond their target number following a sequence of female births.

The conventional instruments, however, are invalid for the present purpose. First, twin births are too infrequent in the data to render a reliable instrument. Second, the size of historical families leaves ample opportunity for giving birth to both males and females: in historical England, average sibship size was 6 to 7 children (Wrigley et al., 1997). This prompts us to search for unconventional instrumental variables. To that end, we investigate the determinants of sibship size in historical context. The size of historical families are essentially controlled by four distinct factors: (i) the age at marriage of the wife; (ii) the death of a spouse; (iii) the fecundity of couples; and finally, since our sibship size measures number of siblings surviving to age five, (iv) child mortality. In the following, we describe each factor, detailing its potential as an instrument for sibship size when relevant.

To begin with, women's biological reproductive period is normally set to range between 15 and 50 years of age. However, since in preindustrial England out-of-matrimony births were disreputable, the age at marriage of a wife would effectively limit her reproductive period from below.

Once a couple was married, it is clear that the death of a spouse would put an immediate halt on a family's reproduction. That fact may have prevented couples from reaching their target fertility, and we cope with this issue below by allowing in the analysis only *completed* marriages. Following Wrigley et al. (1997, p. 359), a marriage is completed if the wife and husband both survived in marriage to the wife turns 50.

In completed marriages, the remaining factor to govern a couple's fertility is their fecundity (child mortality, of course, still affects *surviving* offspring). A couple's fecundity is normally not observed until after the couple ties the knot. It depends on the couple's intrinsic sexual drive, the matching of their genetic material, and the degree of their individual infertility.

Parental fecundity appears to be a useful instrument for fertility. Not only is it exogenous to the couple's decision to educate their offspring. It is also a novel source of exogenous variation in sibship size in the child quantity-quality trade-off literature. A good indicator of a couple's fecundity, according to Wrigley et al. (1997, p. 465), is the time-interval between marriage and first birth. However, before we can proceed to use this as an instrument, two concerns need to be addressed: (i) the occurrence of prenuptially-conceived births, and (ii) age-specific female fecundity. Children conceived before marriage is a prominent feature of English fertility history (Wrigley et al., 1997, p. 421). While no births are reported to have taken place before the time of the marriage, nearly 40 percent of all first-borns were conceived out of wedlock. Some of that might be explained by premature births—yet, no less than 34 percent were conceived within eight months after the marriage.

At first glance, the time-span from marriage to first birth of a prenuptially-conceived child may not tell us anything about the fecundity of a woman. But, as conjectured by Wrigley et al. (1997, p. 422), "it might be expected that such women display higher fertility during the balance of their childbearing life than women whose first child was born more than nine month after marriage, since it might be supposed that women of high fecundity, or perhaps with a greater appetite for sexual activities, would have higher fertility and be more likely to become pregnant before marriage than others." While we proceed to keep couples with prenuptially-conceived births in the sample, we also include a dummy variable to identify affected families. Note, however, that the estimates and qualitative conclusions reached below are robust to the exclusion of affected families.

We also need to correct for the fact that female fecundity decreases with age. We deal with this by controlling for the wife's age at marriage. First, we group marriages by women's age at marriage, and calculate the age-specific mean interval from marriage to first birth. Then, we subtract the age-specific mean from individual intervals. The fecundity instrument used for the analysis below thus captures the interval (measured in years) from marriage to first birth minus the age-specific mean.

The final factor to impact on a couple's reproductive success, as measured by the number of their *surviving* offspring, is child mortality. Variations in child mortality risk influenced by local environmental factors—polluted water, overcrowded areas etc—are arguably uncorrelated with the literacy of offspring when controlling for the relevant parental characteristics. We hence proceed to use variation in parish-level neonatal mortality as an instrument used for checking the robustness of the fecundity instrument. We use mortality rates at parish-level to avoid any direct family-level effects. The reason we use neonatal mortality, which is death within 28 days of birth, is to minimize influence on offspring of parental behaviour.

The mortality instrument is constructed as follows. First, we compute the average neonatal mortality rate of all parishes in the sample. Then, we use a dummy variable to discriminate between parishes below and above the average. Seven parishes—Alcester, Banbury, Bottesford, March, Gainsborough, Great Oakley, Lowestoft—were classified as high mortality parishes, having more than 78 neonatal deaths per 1,000 births. Remarkably, most high-mortality parishes are situated in the English Midlands—a region where neonatal mortality rates are significantly higher, even today, than elsewhere in England (Office for National Statistics, 2009).

4. Data Description and Preparation

The Cambridge Group's data offers 13,625 observations (individuals) with literacy information available. Before we can proceed, however, we need to trim the data in three dimensions. One concerns migration in and out of the parishes observed by the Cambridge Group. This sort of migration constitute a problem when measuring sibship size for two reasons: (i) families may bring children along from non-observed parishes, and (ii) they may move to a non-observed parish and give

TABLE 1. Summary statistics

	Obs.	Av.	S.d.
Non-dummy variables			
Sibship size (all born)	2555	7.34	2.93
Sibship size (surviving to age five)	2555	6.30	2.56
Years from marriage to first birth	2555	1.07	1.04
Dummy variables			
Male	2555	0.43	0.50
Literacy	2555	0.55	0.50
Father literate	1637	0.58	0.49
Mother literate	1591	0.35	0.48
Father manual work	270	0.13	0.33
First-born prenuptially conceived	2555	0.39	0.49
High neonatal mortality location	2555	0.09	0.29

Source: own calculations based on the Cambridge Group's demographic data (Wrigley et al., 1997).

birth to children there. In either case, births may go unobserved. However, someone who is born and dead in a given parish will likely have remained within that parish through their entire life (Souden, 1984). Hence, we can minimize the risk of unobserved births by requesting that parents' birth and death dates are both registered in a given parish. This request narrows the size of our sample down to 4,099 individuals.

The second trimming of the data concerns the fecundity instrument. The time-interval between marriage and first birth requires knowledge about the date of marriage of parents. That we know for 3,472 individuals. Finally, for reasons discussed in the previous section, we only include individuals born into a completed marriage, demanding that wives turn at least 50, and that husbands do not die before this point in time. These requests ultimately leaves us with a sample-size of 2,555 individuals, out of which 98 percent were born between 1708 and 1829. Individuals came from a total of 16 parishes, including Alcester, Ash, Austrey, Banbury, Birstall, Bottesford, Bridford, Dawlish, Gedling, Great Oakley, Ipplepen, Morchard Bishop, Odiham, Reigate, Shepshed and Southill.

Table 1 provides the summary statistics concerning the 2,555 individuals. Among these, 56 percent were females (reflecting the full sample of married individuals). There were 55 percent literate individuals: 62 percent of males and 49 percent of females. Average sibship size was slightly more than seven children. Since children dying young were not a big burden on the household budget, we follow the tradition of demographers and remove from each family children who die before reaching age five. This reduces average sibship size to slightly more than six children per family. The removal of children suffering child mortality has no qualitative implications for the results obtained below. As for the fecundity instrument, the time-intervals range between zero months to more than 10 years, with an average of roughly one year.

Nearly one percent had a time-span of more than five years. The time-intervals concern also incidences of still-births.

We control for two family-background characteristics: parental literacy and occupation of the father. The price of a literate child is arguably smaller for literate parents than for illiterate ones. That may have bearings on the family's trade-off between quantity and quality, and thus demands to be controlled for. The occupation of the father is controlled for since it offers a proxy for household income, a variable not available in the Cambridge data. More well-off families can afford both more children and more education per child, and the occupational status of fathers provides a means to try to take that into account. In very few cases, the data also offers occupational information regarding mothers. However, while wives may have contributed to household earnings to some extent, husbands were indeed the household breadwinners at that time (Horrell and Humphries, 1995).

The Cambridge data includes several hundred occupational titles. In light of the vast variety of professions, we divide up all occupations into two groups: manual and non-manual labour. This division is conducted using the *History of Work Information System*, constructed by the Historical International Social Mobility Analysis project (van Leuwen et al., 2007). While this system permits a subdivision of occupations into a total of twelve social classes, we refrain from a finer division than that between manual and non-manual labour, as this would imply an unrealistic assumption about linearity in the social class division.

Parental literacy and occupation of the father are not available for all 2,555 individuals for which we have literacy information. In 1,637 cases, we have literacy information for fathers, and in 1,591 cases for mothers. 58 percent of fathers, and 35 percent of mothers, were literate. Father's occupation at marriage is known in 270 cases. In order to keep all 2,555 observations in the sample, we proceed to generate dummies concerning knowledge about father's and mother's literacy; these are set to zero whenever literacy information is unavailable. This means that the background-variable in the analysis below is 'literacy unknown'. Similarly, we construct a dummy for occupation of the father (manual or non-manual labour) with 'occupation unknown' as the background variable.

5. Analysis and Results

We now advance to estimate the effect of family sibship size on individual literacy using OLS and 2SLS (instrumental variable) regression analyses. The OLS model is given by the following equation:

$$literacy = \alpha_0 + \alpha_1 sibshipsize + \alpha_2' X + \varepsilon, \tag{1}$$

where X is a vector of covariates, and ε is an error term. Covariates comprise sex, parental literacy, occupational status of the father, as well as dummies for time (centuries since 1580), birth order, prenuptially-conceived first-births, and missing information regarding parental literacy and occupation of the father. We use the same covariates in both the OLS and the 2SLS regression analysis.

As discussed earlier, the OLS estimate may be biased, and an observed negative association between sibship size and literacy may not have a causal interpretation. In case of simultaneity, if literacy depends negatively on fertility, and fertility depends negatively on literacy, then the OLS estimate of α_1 will be downward biased. On the other hand, if literacy and fertility are both positively correlated with an omitted variable, then the estimate of α_1 will be upward biased. As explained above, we attempt to tackle the potential problem of endogeneity by use of 2SLS analysis. Specifically, the first step predicts family sibship size using our instrumental variables as well as covariates. The second step then predicts literacy using equation (1) above. The first-stage regression equation hence reads

$$sibshipsize = \beta_0 + \beta_1' IV + \beta_2' X + \nu,$$

where IV is a vector of instrumental variables, X the covariates, and ν is an error term. We estimate the model using three different instrumental variable specifications: parental fecundity, parish-level neonatal mortality and a combination of the two.

All estimation results are reported in Table 2. Dummy-estimates for birth order, prenuptially-conceived first-borns, as well as missing observations, are all excluded from the table. Observations are clustered by family—the 2,555 individuals in the sample came from a total of 1,127 different families.

Beginning with the OLS results, the conditional correlation between sibship size and literacy is negative and statistically significant at the 1 percent level. Each additional sibling reduces the chances of literacy by 1.5 percentage points among all family siblings. This is a fairly modest effect, but we know it may be biased. Turning 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 (16 percentage points). Children of literate parents are more likely to be literate themselves (25 percentage points in case of literate fathers; 24 percentage points in case of literate mothers). If both parents are literate, therefore, then that raises the chances of literacy among their offspring by nearly 50 percentage points. Finally, time is a crucial factor: for each century passing after 1580, offspring have 14 percentage points higher probability of being literate.

Table 2 also reports the results of the IV regression analyses. Columns 2, 4, and 6 detail the results of the first-state regression estimates, and Columns 3, 5, and 7 the findings of the second stage. In all three cases, the Wald F-statistic values—based on the Kleibergen-Paap rk statistic (Kleibergen and Paap, 2006)—are well above 10, suggesting no signs of weak instruments (Baum and Schaffer, 2007). If at least one instrument is truly exogenous—and that we believe is the case with fecundity—then we can make a joint test of both instruments being exogenous. Since our observations are clustered by family, this test is performed using the Hansen J-test (Hansen, 1982). The J-statistic is 0.152, corresponding to a p-value of 0.697. Hence, we cannot reject the null, which suggests that the two separate instrumental variables—fecundity and mortality—are both valid.

Using parental fecundity as an instrument for sibship size, the first-stage effect of one additional year above the age-specific mean birth-period is -0.39 surviving children (Column 2). This indicates that low-fecundity couples on average had fewer children throughout their reproductive life. The second-stage estimate (Column 3) supports the finding of a trade-off from the OLS analysis, but the numerical effect is six times bigger: each additional sibling reduces the chances of literacy by 9.3 percentage points among all siblings for the family. The estimate is significant at the 1 percent level.

The mortality instrument confirms the results. The first stage (Column 4) finds that families in high-mortality parishes had on average 1.2 fewer surviving children

Table 2. Estimation results

	(1) OLS	(2) First stage	(3) Second stage	(4) First stage	(5) Second stage	(6) First stage	(7) Second stage
Sibship size	-0.0148***		-0.0928***		-0.112***		-0.102***
	(0.00565)		(0.0320)		(0.0376)		(0.0245)
Fecundity		-0.390***				-0.392***	
		(0.0592)				(0.0580)	
Mortality				-1.204***		-1.212***	
				(0.210)		(0.203)	
Male	0.157***	0.167*	0.169***	0.126	0.171***	0.142	0.170***
	(0.0203)	(0.0906)	(0.0218)	(0.0905)	(0.0224)	(0.0896)	(0.0217)
Mother literate	0.254***	-0.0161	0.250***	0.00140	0.249***	0.0361	0.249***
	(0.0359)	(0.224)	(0.0394)	(0.223)	(0.0413)	(0.221)	(0.0402)
Father literate	0.239***	0.325	0.266***	0.363*	0.272***	0.345	0.268***
	(0.0357)	(0.214)	(0.0405)	(0.213)	(0.0423)	(0.213)	(0.0404)
Father non-manual work	0.0540	-1.077***	-0.0230	-0.836**	-0.0422	-0.924**	-0.0316
	(0.0654)	(0.361)	(0.0691)	(0.361)	(0.0710)	(0.361)	(0.0656)
First-born prenuptially conceived	0.0186	0.124	0.0590*	0.474***	0.0691*	0.0769	0.0635*
	(0.0263)	(0.166)	(0.0339)	(0.149)	(0.0367)	(0.164)	(0.0328)
Centuries since 1580	0.139**	1.087***	0.221***	1.057***	0.241***	1.095***	0.230***
	(0.0606)	(0.319)	(0.0780)	(0.318)	(0.0837)	(0.313)	(0.0763)
Observations	2555	2555	2555	2555	2555	2555	2555
Families	1127	1127	1127	1127	1127	1127	1127
Kleibergen-Paap F			43.54		33.01		41.55
Hansen J							0.697

Robust standard errors clustered by family in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All regressions include dummies for birth order from one to nine children, as well as for missing observations of parental literacy and father's occupation.

compared to their counterparts in low-mortality parishes. The second-stage estimate suggests that each additional sibling reduces the chances of literacy by 11.2 percentage points among all siblings. This, too, is significant at the 1 percent level. While the estimates of the two instrumental variables are less than one standard deviation apart, the OLS estimate falls well outside the 95-percent confidence interval of both IV estimates. Last but not least, the combined-instruments estimate (Column 7) yields a trade-off of -10.2 percentage points. This is also significant at the 1 percent level. With a standard deviation less than five times the standard error of the OLS estimate, the combined instruments provide the most accurate estimate among all *IV* regressions.

Finally, we test the exogeneity of the sibship-size variable using the Durbin-Wu-Hausman test, which we conduct according to Baum et al. (2007). The p-value is less than 0.01 in all three cases, confirming that the OLS estimate is indeed downward biased.

6. Concluding Remarks

The literature on long-run economic growth usually emphasizes the interaction between demographic variables and human capital accumulation as a prominent source of growth and development (Galor, 2005). That conclusion builds largely on theoretical inferences, leaving something to be desired in terms of exploring the empirical record. This study offers a first attempt to analyze the child quantity-quality trade-off for historical England. By use of instrumental variable regression analysis, we find a negative and strongly significant causal effect from family sibship size to individual literacy. The magnitude of the trade-off—a 10 percentage-points cut in the chances of offspring literacy for each additional surviving child—implies a substantial decrease in offspring quality among large families.

Our findings lend strong support to 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 (fertility decline) 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 argue that the trade-off is decisive to economic advancement, not just from the onset of the demographic transition, but throughout human evolution.

Finally, a recent study by Becker et al. (2009)—the first attempt to analyze the historical record—finds a significant trade-off effect using a census-based dataset for 330 Prussian counties in 1849. Together with the present findings, this suggests that the trade-off was vividly present in historical societies.

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