Malthus to Modernity: Income, Fertility and Economic Growth in England, 1500-1914

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Abstract

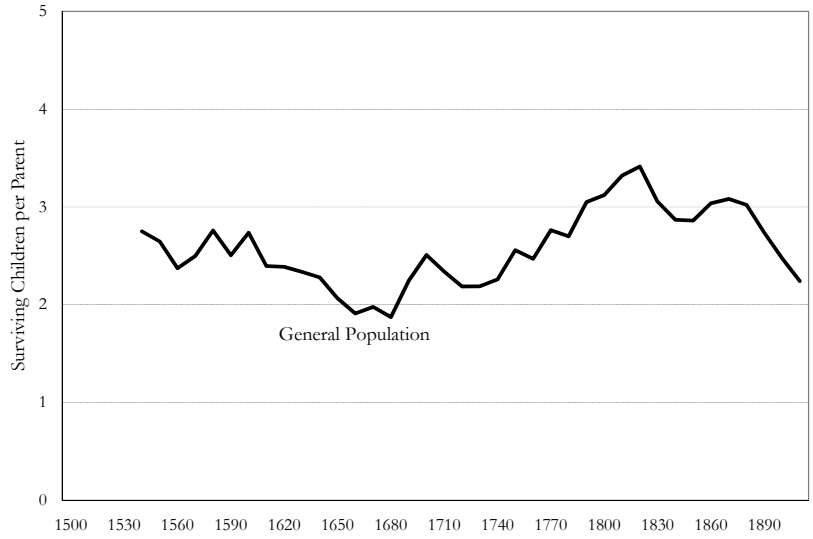
The Industrial Revolution seemingly involved two profound changes separated by 120 years: the classic Industrial Revolution of 1770, and the demographic transition of 1890. The first was the appearance of higher innovation rates, creating modern rates of output growth. The second a decline in fertility, first in the upper classes, then among the masses, that channeled all economic growth into higher living standards. That 120 year chasm has been unbridgeable in unified accounts of the transition to modern growth. Measuring economic status and net fertility from wills we show that the demographic transition actually coincided with the Industrial Revolution. Net fertility among the rich fell rapidly towards modern levels after 1770. But aggregate fertility rose in these years because net fertility among the poor at the same time rose to equal that of the rich. Only in the 1890s did aggregate fertility rates begin to decline.

Introduction

The two great events that created the modern economic world were the Industrial Revolution and the Demographic Transition. The Industrial Revolution increased rates of growth through the supply for the first time of a constant stream of innovations. Before the Industrial Revolution, however, all technological advance had been absorbed in raising the stock of people, not in raising living standards. In the pre-industrial demographic regime, at least in England, higher income groups had substantially higher net fertilities. Had the pre-industrial demographic regime continued then much of the accelerated efficiency advance of the economy would similarly have been consumed in maintaining ever larger populations. Eventually in England, for marriages formed in the 1890s and later there was a substantial decline in gross fertility levels, and hence a dramatic slowing of population growth rates. After 1910 most economic growth went into raising living standards, not increasing populations.

The Industrial Revolution can be dated to 1770-1800, while the Demographic Transition is a phenomenon of the years 1870-1910. Thus there is a 100 year gap between these two events. Figure 1, for example, shows the number of surviving children per woman in England by decade from the 1540s to the 1910s from Wrigley and Schofield. Only in the late nineteenth century is there any sign of a decline in net fertility. The Industrial Revolution itself is associated with an increase in net fertility which led to an unprecedentedly fast rate of population growth in England in these years.

Figure 1: Net fertility trends in England, 1540s-1910s



Source: Wrigley and Schofield, 1981, 528-9, table A3, Wrigley, 1969, 196, Table 5.16.

Attempts to develop unified models of the transition to modern economic growth, particularly those that emphasize human capital investment, have grappled unsuccessfully with this huge delay in the onset of the Demographic Transition. In particular in England the Industrial Revolution coincided with an increase in fertility, not a decline.

Here we show that starting with the generation born in the 1770s there were in fact significant changes in fertility in Industrial Revolution England. In particular economically successful men switched from levels of net fertility of 4-5 children, to levels of 2.5-3, close to the general population. This important switch does not show in the aggregate data because at the same time the net

fertility of poorer individuals, the bulk of the society, increased in these years to equal that of the rich.

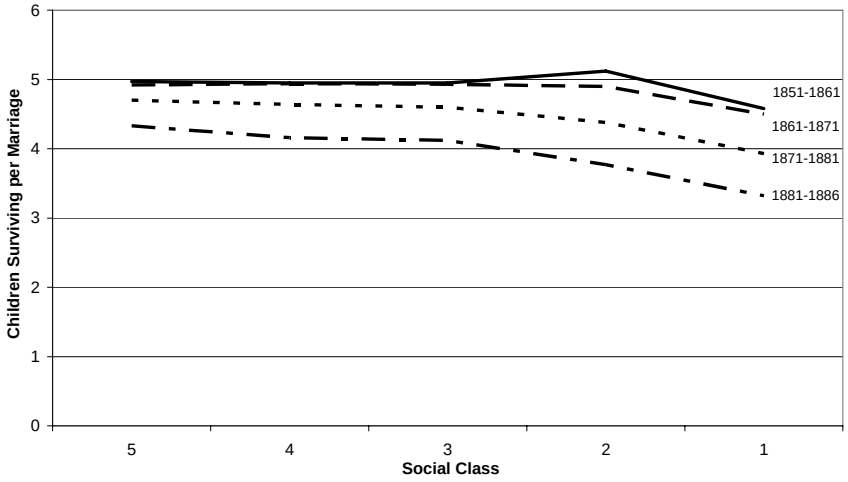
Thus by the time of the onset second fertility transition in 1870-1910 the net fertility of the poor is if anything higher than for the rich. This creates the false impression that the fertility regime of the early and middle nineteenth century somehow represents the entire pre-industrial period. In fact it is a very different regime, and close to that of the modern world. Amazingly, despite the enormous quantities of research into the demographic experience of pre-industrial England we seem to have missed a profound transformation in the demographic regime that was occurring simultaneously with the Industrial Revolution.

The Method

We know a lot about aggregates levels of gross and net fertility in England from 1540 onwards from parish records (until 1837) and then from general birth registration. Parish records however, reveal nothing of the economic and social status of parents. Thus we have much more limited information on both gross and net fertility as a function of wealth and social status before a report associated with the 1911 census that correlated fertility with occupational status for marriages formed from 1851 onwards.

Figure 2 shows what this 1911 report suggests. It shows net fertility for marriages of 25 or more years duration by social class, where the lower numbers are higher classes, by marriage cohort

Figure 2: Net Fertility by Social Class, 1851-1886



Source: Census of England and Wales, 1911, ---.

starting in 1851-60. Before 1871 it seems that there is little or no difference in fertility by social class, with the net fertility of all these groups relatively high. The conventional picture for England before 1871 is thus that fertility within marriage was unregulated for marriages formed before 1871, with only the lat average age of marriage, and the substantial percent never marrying limiting gross fertility. There was only one fertility transition which began sometime after 1871.

Here we develop a source which allows us to examine both gross and net fertility as a function of wealth and social class for cohorts born before 1820. This is the wills of male testators. Men only were used since for most of the period women had only residual claims on their property after marriage, and left wills typically only if single or widowed. There are millions of extant

wills in England for the years after 1400, and a significant fraction have been transcribed and abstracted. The wills before 1858 come mainly from local Ecclesiastical courts in Essex, Suffolk and Surrey (before 1858 church courts handled all matters of wills and testaments). Some also come from the Prerogative Court of Canterbury, which handled estates of higher value with assets distributed across a wider area. After 1858 the wills come from the records of the Principal Probate Registry in London which has preserved all probated wills in the south of England after 1858.

For wills after 1841 we are also able to link many testators to individual census records giving the age of the testator at death. For the earlier wills we can get the age at death for a subset of the testators from parish records giving baptisms and marriages.

For those testators where we do not have a direct estimate of age at death we can infer this from the observed features of the testator such as their marital status, numbers of children reported in the will, numbers of grandchildren, whether one of their parents is alive, and whether they have a child aged 21 or above. Appendix 1 reports the various methods used to fill in missing values for testators. The regression used to predict age has an R^2 of 0.49. Thus we are able to form cohorts of male testators by birth year.

The assets of testators were estimated in two ways. For many wills probated in 1786 and later we get an estimate of the "personalty" – assets other than real estate – from estate tax declarations. We add these to estimates of real estate from houses and land mentioned in the will to get a total value of the bequest. In only about 20% of cases where land was bequeathed was the area of

the land indicated. But we are able to approximate the area from other details of the will such as the testators occupation and cash bequests. Appendix 2 details how the area of land bequeathed was estimated in the remaining 80% of cases.

The major flaws with using probate valuations as true measures of wealth other than real estate are the omissions of settled property and debts and credits (Owens et al 2006, 384). Before 1898, the reported probate valuations are estimates of "the gross value of an individual's unsettled personal property", and were estimated for tax purposes (Owens, Green, Bailey and Kay 2006, 383). After 1898, settled property was included (Rubinstein 1977, 100). The executors or administrators of the wills submitted estimates, and because of a fine for undervaluation "the gross valuation was always likely to be an upper estimate of an individuals worth" (Owens et al. 2006, 386).

This "gross" estimate omitted any debts or credits due by or to the deceased individual. For the period after 1881, Rubenstein estimates that the difference between the gross and net value of an estate, was on average 5 to 15% (Owens et al 2006, 387). Before 1881, effects are reported as an approximation, under a certain set threshold level (e.g. under £50, under £100). As Owens et al. noted, the effect of these tax bandings is to inflate the already rough estimates of wealth (Owens et al. 2006, 387).

For earlier years the estimated assets of testators were constructed from the information in wills by adding together the cash payments directed by the testator, with the estimated value of houses, land, animals, grain bequeathed by the testator.

For a subset of 506 wills we have both estimates. In these overlapping cases the bequests estimated in the second fashion are 0.66 of the bequests estimated in the first way. For consistency the first set of estimates was thus multiplied by 0.66. All values were deflated to a common price level of the 1630s to get a unified measure of the real bequest over the entire period.

In the course of the years 1500-1914 the real rate of return on assets in England declined significantly. The annual real purchasing power associated with a £1 of assets thus declined significantly over time as interest rates fell. We thus calculated an expected "bequest income stream" for each testator over time as a better way of quantifying the average value of the bequest.

Table 1 summarizes by period the numbers of men for which we have information on assets at death and numbers of surviving children by half century birth cohorts. We have 6,714 wills coded so far, with about 200 per decade for men born between 1700 and 1850.

We also coded the occupations of the testators into 7 socio-economic status categories. These differ from the more modern socio-economic status classification because of the prevalence in status descriptions on wills even as late as the late nineteenth century of such terms as "yeoman," "husbandman" and "gentleman." But they do seem to capture socio-economic differences. Table 2 shows for men born before 1770 by socio-economic status average assets, the percent literate (as revealed by a signed will), and average age at death. Average assets and literacy were strongly correlated with the assigned socio-economic status. And there was also some correlation of the estimated age of death,

Table 1: Summary of the Wills Data

Period	N	Ave Assets (£)	Ave Asset Income (£)	Ave Age at Death
1450-99	200	246	17.0	53
1500-49	589	440	31.5	56
1550-99	1,967	357	25.9	54
1600-49	236	514	36.2	52
1650-99	307	537	33.5	61
1700-49	1,083	451	25.2	62
1750-99	1,139	970	48.7	64
1800-49	1,140	2,808	138.7	65
1850-79	53	2,065	106.7	-*

Note: *The 1850-79 cohort has a censored age distribution.

with gentry testators on average dying 5 years later than laborers.

Table 3 shows similar correlates of socio-economic status with assets and average age at death for men born after 1770. Again socio-economic status correlates strongly with average assets, and is also correlated with average age at death. Now the average for the gentry is 70, as opposed to 64 for laborers.

Table 2: Social Status, Assets and Literacy, pre 1770 births

Social group	N	Average assets (£)	% literate	Ave Age at Death
Gentry	229	2,030	90	59
Merchants/ professionals	189	922	96	55
Farmers	1,551	516	61	59
Traders	437	360	74	56
Craftsmen	791	239	64	57
Husbandmen	609	148	36	55
Laborers /Servants	207	104	23	54

The numbers of surviving children for each testator were estimated from the wills in three ways. First there are wills where all the children were recorded. Here we counted dead children who had produced children of their own as "surviving" children also. Next there were earlier wills where girls tended to be omitted. In wills written before 1550 substantial numbers of daughters are omitted where there is a male heir. Thus the average family which reported one male heir after 1550 reported 1.55 daughters, but before 1550 only 0.89 daughters. We thus have to infer the number of daughters for wills before this date. We do so by multiplying each reported daughter in a will by 1.49, to get an estimated total number of daughters. Finally there are

Table 3: Social Status, Assets and Average Age, post 1770 births

Social group	N	Average assets (£)	Ave Age at Death
Gentry/Independent	176	5,612	70
Merchants/ professionals	317	3,855	67
Farmers	355	1,692	65
Traders	446	1,816	64
Craftsmen	341	842	63
Husbandmen	99	438	65
Laborers/Servants	61	259	64

wills where besides the children specified there were also indications of an unspecified number of additional. Where we could determine in a will that the number of children was "≥ n" we estimated the expected number of children from the average of wills in this category (see the appendix).

Estimating net fertility from wills will always tend to produce a lower bound estimate, since the errors will typically be the omission of some children from the will. But the wills will show

Table 4: Net Fertility Averages (outside London)

Birth period	N	% Single*	Ave. children married	Ave children all
1450-99	200	3	3.49	3.39
1500-49	589	3	3.40	3.30
1550-99	1,967	11	3.20	2.85
1600-49	236	17	3.15	2.61
1650-99	307	13	3.28	2.85
1700-49	1,083	15	3.07	2.61
1750-99	1,139	17	3.05	2.53
1800-49	1,140	-#	2.78	-

Notes: *The percent single includes some childless widowers whose earlier marriage was not revealed by the will.
#The sample in these years was collected in such a way that single men were less likely to be sampled.

relative net fertility levels by asset wealth, by socio-economic status, and over time.

Table 4 shows by birth half century the percentage of men dying never married, as well as the average number of surviving children per married or widowed man, for men dying outside

London.[1] If a man is a widower without any surviving children, then there may be no evidence in the will of his earlier marriage. Thus the estimate of the percentage single is an upper bound. The final column shows the overall implied net fertility for testators. If we compare these net fertility rates to the national totals calculated by Wrigley and Schofield, shown in figure 1, we see that the net fertility of testators is above that of the general population until the 1750-99 cohort when it drops substantially below. Below we will derive a more precise estimate of net fertility by decadal birth cohorts for the poorest testators that we can compare to the national averages.

A Demographic Revolution?

For birth cohorts earlier than the 1770s, and thus typically for marriages formed before the 1800s, there is a strong positive association in all periods between wealth at death and net fertility. But with surprising rapidity this association disappears for the generations of men born in the 1770s and later. That disappearance involves both a substantial decline in the net fertility of the richer testators after 1770, but also a modest but quite significant increase in the fertility of the poorest testators.

To demonstrate this we divide testators into rough quartiles, based on the implied income stream from the assets of the sample of testators as a whole. Thus in each period the poorest group are those with an implied asset income below £6 per year (in 1630s prices), the richest are those with implied asset incomes above

[1] London had a distinctive and different demographic regime for men born before 1810.

£31. We then estimate for ever married men the coefficients of the regression

$$N = a + \sum b_j DINCQ_j + \sum c_j D1770 \cdot DINCQ_j + h_1 DLON + h_2 DTOWN + h_3 DFARM + e$$

where N is the number of surviving children, $DINCQ_j$ an indictor for each of the four asset groups, D1770 an indicator for a testator born after 1770, and DLON, DTOWN and FDARM indicators for testators living in London, some other town, or on a farm (with these effects being estimated separately for cohorts born before 1760, 1760-1809, and 1810 or later). Table 5 shows the estimates of these various effects for the whole panel of wills. Also shown are the implied levels of net fertility for men of the four wealth classes who were resident in country villages before and after 1770. The wealth effect on net fertility is very powerful statistically and quantitatively for men born before 1770, but completely absent for those born after this. Wealthier men born before 1770 also have net fertilities well above those of men in the general population. After 1770 a completely new relationship between wealth and fertility emerges, much more like that of the modern world, where if anything the testators as a whole now have lower fertilities than the general population.

The change in behavior for both groups is remarkably fast. Table 6 shows by twenty year periods around 1770 the net fertilities of the richest and poorest testators. The drop in net fertility for the rich is immediate after the 1770 birth cohort. The rise in fertility by the poorest group is potentially a little more protracted. While measured net fertility rose for the 1770-89 cohort, it was not any higher for the 1790-1809 cohort, so that the

Table 5: Children per married man by wealth

Coefficient	Estimate	Standard Error	Implied Level
Constant	0.880	.027	
Assets 1	0.000	-	2.41
Assets 2	0.198**	.035	2.94
Assets 3	0.348**	.034	3.41
Assets 4	0.555**	.036	4.20
Assets 1 – 1770	0.191**	.046	2.92
Assets 2 – 1770	-0.039	.055	2.83
Assets 3 – 1770	-0.168**	.051	2.89
Assets 4 – 1770	-0.373**	.041	2.89
DLON pre 1760	-0.675**	.068	
DLON 1760-1809	-0.221	.135	
DTOWN pre 1760	-0.203**	.048	
DTOWN 1760-1809	-0.145**	.051	
DFARM pre 1810	0.122*	.027	

Note: Because N is a count variable the regression was estimated as a negative binomial. The estimated coefficients thus have to be exponentiated to get the fertility levels by asset class.

Table 6: Net Fertility by Birth Cohorts

Birth Cohort	Obs	N poor	N Rich
1690-1709	179	2.54	3.78
1710-29	315	2.32	3.79
1730-49	499	2.41	4.20
1750-69	350	2.37	4.29
1770-89	384	**3.17**	**3.06**
1790-1809	459	**2.39**	**2.37**
1810-29	508	**3.05**	**2.97**
1830-49	302	**2.68**	**3.06**
1850-69	46	**2.90**	**2.88**

Table 7: Net Fertility by First Marriage Cohorts

Marriage Cohort	Obs	N poor	N Rich
1720-39	176	2.52	3.89
1740-59	345	2.27	3.74
1760-79	502	2.37	4.42
1780-99	330	2.50	4.15
1800-19	397	**2.98**	**2.97**
1820-39	458	**2.67**	**2.41**
1840-59	528	**2.90**	**2.88**
1860-79	255	**2.83**	**3.17**

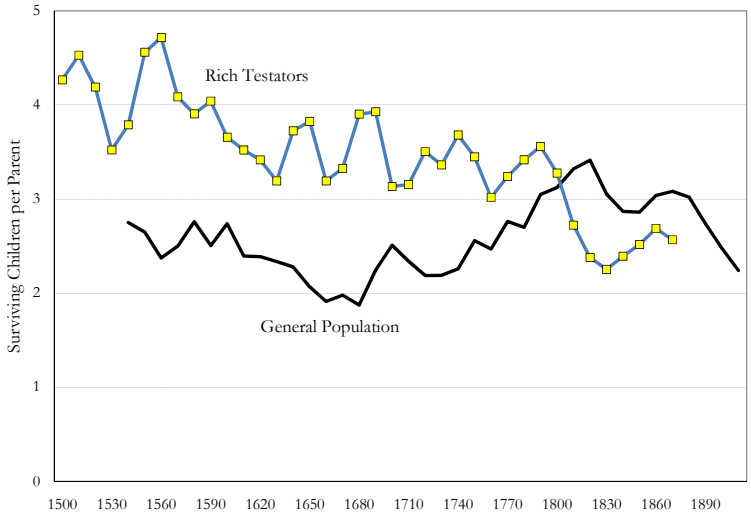
true date of transition could be anywhere between the 1770 and 1810 cohort.

The change is indeed even slightly more abrupt statistically if instead we organize testators by the estimated date of their first marriage. In this case it is marriages formed in 1800 or later which first show the absence of a wealth gradient to net fertility. Table 7 shows the transition measured in terms of first marriage cohorts.

Figure 3 shows the implied net fertility of the top quartile by wealth of male testators, by decade of marriage, from the 1500s to the 1870s, adjusting for location and the share of men single. In comparison is shown the implied net fertility of all men in England from Wrigley and Schofield. Rich testators have a significantly higher net fertility than the population of England as a whole until the 1800s. Then their net fertility falls below that of the general population. Their fertility falls just as that of the general population increases.

Since wealth was associated with social class, before 1800 high status groups such as the gentry, professionals and farmers had higher fertility than low status groups such as laborers. After 1800 this status differential ends. However fertility seems to attach to social status only because of the average wealth differences between the different groups. Once we control for wealth, status differences in net fertility disappear before and after 1800.

Figure 3: Net fertility, general population and rich testators



Note: The observation for testators for the 1500s is the average of the 1490s and 1500s first marriage cohorts, and so on.
Source: As figure 1.

The mechanics of the convergence in fertility of rich and poor testators for marriages after 1800 is unclear. Table 8 shows median ages of marriage for male testators, outside London, by asset class before 1800, and 1800-59. The age of marriage is estimated for this group by matching them to parish records of marriages and births and baptisms. There is little sign of any significant change. In particular the sharp decline in net fertility by the rich is not explained by any move to later marriage ages by men. There is less data for wives, but table 9 shows that similarly for women there is no sign of any change in behavior pre and post 1800, and no sign of any difference among wealth classes. The timing of marriage plays no role in this profound change.

Table 8: Median Marriage Ages by Asset Class, pre and post 1800 Marriages, Testators

Assets	N	Pre Median	N	Post Median
1	43	28.8	66	26.1
2	78	26.1	38	24.6
3	82	26.5	39	26.8
4	69	27.6	87	27.7
All	273	26.9	230	26.3

Table 9: Median Marriage Ages by Asset Class, pre and post 1800 Marriages, Wives

Assets	N	Pre Median	N	Post Median
1	21	22.7	51	22.9
2	31	25.2	25	22.5
3	38	23.9	24	23.2
4	35	22.3	68	23.2
All	126	23.8	168	23.0

Using the link to parish records of births and baptisms we also estimate for a subset of testators survival rates for children by wealth class for marriages before and after 1800, and the implied gross fertility rates by wealth class. For each testator we have the number of births identified in the parish records, as well as thenumber of those children mentioned in the will. Table 10 shows this data, for testators living outside London. This generates an implied survival rate for children.[2] However, the small numbers of testators linked so far to parish records, particularly after 1800 makes the results here subject to significant sampling error.

Before 1800 the higher wealth classes have a significantly better child survival rate, 71% as opposed to about 61% for the poorer. After 1800 the survival rate for the children of the poorer testators rises to close to 66%, while that of the rich falls. The small sample sizes after 1800 preclude determining whether these are just the result of sampling error, or represent real changes. The overall impression is that for testators as a whole there was a modest decline in survival probabilities for children after 1800.

Table 11 shows the gross fertility rates the data in table 10 implies by wealth classes before and after 1800. For the richest there is still the clear implication that their gross fertility fell significantly in marriages formed after 1800. For the poorest gross fertility seems to have risen. Thus the equalization of net fertilities across rich and poor testators was mainly the product of

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2 In this exercise we counted as survivors only children still living at the time of the will, not those dead but with surviving children of their own.

Table 10: Survival Rates by Asset Class, pre and post 1800

Asset Group	N	Births	Survivors	Survival Rate
PRE 1800				
1	140	491	306	0.62
2	186	761	456	0.60
3	223	1,042	738	0.71**
4	210	995	692	0.70**
All	759	3,289	2,192	0.67
POST 1800				
1	31	100	64	0.64
2	28	87	58	0.67
3	34	133	77	0.58
4	65	262	157	0.60
All	158	582	356	0.61

Note: ** = Significantly different than for asset class 1 at the 1% level.

Table 11: Net and Gross Fertility, pre and post 1800

Asset Group	Net Fertility Pre 1800	Gross Fertility Pre 1800	Net Fertility Post 1800	Gross Fertility Post 1800
1	2.37	3.80	2.84	4.43
2	2.96	4.94	2.54	3.80
3	3.46	4.88	2.80	4.83
4	4.25	6.11	2.83	4.72
All	3.26	4.93	2.75	4.45

a tendency towards equalization of gross fertility rates per year of marriage between rich and poor after 1800.

In terms of diagnosing the mechanics of the Demographic Revolution we have uncovered, a further feature we can observe in some cases is the birth intervals, and the interval between marriage and the last birth. Fertility among the rich could have been reduced as a combination of two different forces. The first is "spacing" – adopting practices that increase the interval between births. The second is "stopping" – keeping birth spacings the same but terminating the sequence of births earlier. The demographic transition of the late nineteenth century has been attributed to "stopping" primarily. It is interesting thus to ask which force explained this earlier decline in the fertility of the rich.

Table 12 shows the statistics on this for our testators for marriages before and after 1800. Given our partial data from links to parish records we estimate only the 1-2 birth interval, and the time from marriage to the last observed birth. The 1-2 birth intervals clearly suggest that the differences in gross fertility between rich and poor before 1800, and the declining gross fertility of the rich after 1800, are not explained by any differences in spacing intervals. Earlier stopping must explain the lower fertility of the poor before 1800, and the decline in fertility of the rich after 1800.

Given our partial data on birth dates calculating the time to the last birth is much more difficult. If, for example, of n births in a family the timing of only 1 is observed, then on average the calculated fertility span would be half the actual fertility span. Our estimates of this will thus have a downward bias. The table reports nevertheless the average time between marriage and the last observed birth. It is still an underestimate of the likely true fertility span, but is not far from an analogous figure for the general population reported in Wrigley et al., 1997.

Before 1800 the higher fertility of the rich shows up in a higher fertility span. For asset group 4 this was 12.7 years compared to 9.0 for asset group 1, a quantitatively and statistically significant difference. The lower family sizes of the poorer testators were mainly explained by an earlier cessation of reproduction. Similarly when the fertility of the rich declined after 1800 that was again associated with the earlier stopping of births within marriage.

Table 12: Birth Intervals

Asset Group	N	Interval births 1-2	N	Interval marriage-last
PRE 1800				
1	66	2.23	121	9.0
2	118	2.29	162	10.4
3	145	2.28	189	12.2**
4	130	2.29	170	12.7**
All	461	2.27	642	11.3
POST 1800				
1	29	2.03	63	9.6
2	19	2.33	34	9.5
3	14	1.96	31	9.8
4	38	2.19	76	10.3
All	100	2.14	204	9.8^^

Note: ** = Significantly different than for asset class 1 at the 1% level.

^^ = Significantly different than for before 1800 at the 1% level.

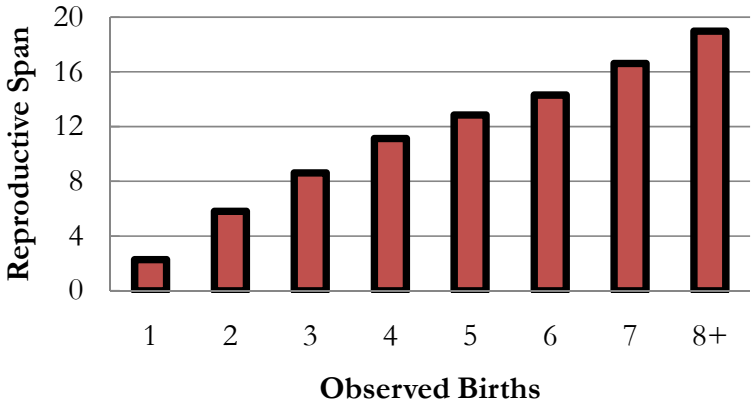
If all of the differences in fertility over time and between wealth classes were caused by differences in stopping behavior then when we estimate the reproductive span controlling for the number of children these other variables should have no effect. That is if we run the regression

$$SPAN = a_0 + a_1 N + \sum b_j DINCQ_j + \sum c_j D1770 \cdot DINCQ_j + e$$

the coefficients b_i and c_i should all be insignificantly different from 0. This indeed is the result we find. Grouping families into those of 1, 2, 3, 4, 5, 6, 7, and 8+ observed children we find the observed reproductive span is heavily dependent on the number of births observed. Figure 4 shows the pattern for the poorest group of testators before 1800. But once observed births are controlled for it does not change for marriages after 1800, and it does not vary across wealth classes. A family with 8 or more births observed would have a predicted reproductive span of 19 years for the poorest testators before 1800, and 18.8 years after 1800. For the richest testators before 1800 the predicted span would be 19.2 years, after 1800 19.1 years.

Thus the major observed direct correlate of the earlier fertility differences, and the later convergence in fertility is variations in the reproductive span of marriages.

Figure 4: Observed Births and the Reproductive Span



Explaining the Demographic Revolution

The wills data clearly indicates that a Demographic Revolution accompanied the Industrial Revolution. Net fertility within marriage fell sharply for the richest testators, starting with marriages commencing in the 1800s. This occurred, however, at a time of generally increasing fertility rates amongst the poorer population, concealing this trend in the aggregate data. The source of the decline in the fertility of the rich implies that it had to be a conscious control of fertility, through *coitus interruptus* or other early birth control methods.

Could this just be a product of income? That is, could the general rise in incomes in the Industrial Revolution have led the population into the range where for the richest they entered a level

of income beyond which the modern negative association of income and fertility finally emerged?

Evidence from the years before 1800 suggests this cannot be the explanation. For these years we can split up the testator population into even finer gradations of assets, and examine whether at very high asset levels even before 1800 net fertility declines. The answer is a resounding "no". For the years before 1800 no matter how high we go in the asset range, net fertility continues to climb. The richest testators before 1800, those with asset incomes exceeding £200 per year (in 1630s prics), had an average of 5 surviving children, as figure 5 shows. This group had average asset incomes well above the asset group 4 in our sample after 1800, yet they had nearly double the net fertility of that later group. Income alone cannot explain the change in fertility behavior for marriages 1800 and later.

Further casting doubt on the role of income, estimates of both income per person and real wages suggestion that it was only in the 1820s that there was any significant rise in real incomes and real wages as a result of the Industrial Revolution. Figure 6 shows the real wages of craftsmen in England for the years 1720-1914. The change in marital fertility clearly predates any significant income increases, and occurs more rapidly than a gradual rise in incomes would induce.

The inceasing importance of human capital in the production of income again will not help explain the 1800 Demographic Revolution. For a start, for those whose income depended largely on the possession of land or houses – landed proprietors and

Figure 5: Asset Income and Net Fertility before 1800

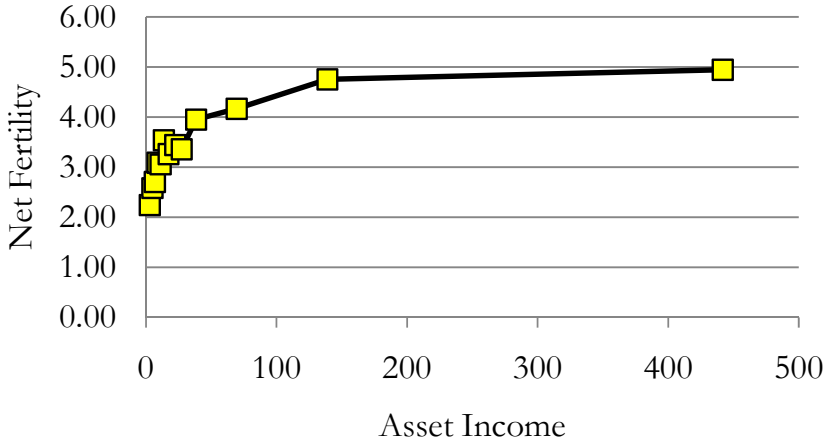
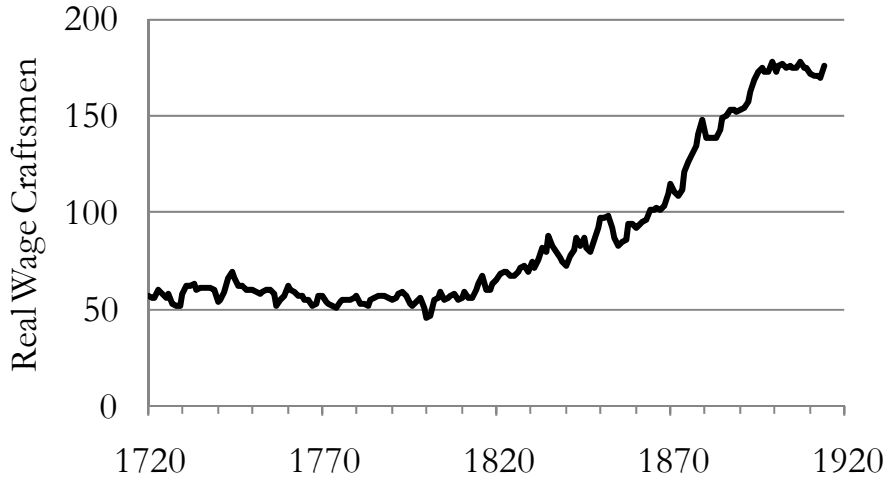


Figure 6: Real Wages of Building Craftsmen, 1720-1914



Source: Clark, 2005.

rentiers – always had an even stronger incentive to limit fertility if they wanted to maintain the living standard of their children. The family assets would get divided up among the children, so that with more than two children average expected assets per child would decline.[3] In a world where education was the key to income, since there was a maximum cost of education, the richest could afford to have as many children as they wanted and still give them all the maximum possible amount of education.

Another potential explanation of a decline in net fertility among high income groups is a decline in child mortality. For the testators where we observe ages we see a fairly steady increase between 1580 and 1914 in the average age of death. The average age of testators rose from about 55 in 1600 to 68 by 1910. However this trend is gradual while the change in net fertility is more sudden. Nevertheless one idea is that in pre-industrial society men had to have as many children as possible in order to maximize the chance of an heir. The hazards of survival meant that even with relatively high net fertility rates a substantial fraction of men would die with no child to inherit. As infant and child mortality declined, eventually families could ensure an heir with many fewer children. There was more certainty that if a child was born he would survive to adulthood. Consequently net fertility declined.

The empirical content of this idea would be that declining net fertility for the rich in the later nineteenth century would be associated with a larger fraction leaving at least one surviving

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[3] Spouses would also bring assets to marriages, so that a child with half the assets of a parent would on average end up in a family with assets equal to that of the parental family.

Table 13: Wealth at Death and Chances of a Surviving Child

Period of marriage	Assets 1	Assets 2	Assets 3	Assets 4
1490-1799	0.81	0.84	0.87	0.91
1800-1859	0.82	0.80	0.81	0.79

Note: These odds were estimated from a logistic regression.

child. Table 13 contains a simple test of this idea. It records the estimated probability of a man leaving a surviving child at different epochs and asset levels. Before marriages commenced in 1800 and later rich men were left without a child as heir far less often than poor men. However after 1800 the chance of a rich man leaving a child as heir declined significantly from around 0.91 to 0.79. Thus the interpretation that the changed behavior of the rich was a response to declining mortality rates cannot be sustained. As table 10 showed there is actually no sign of any improvement of the survival rate of children pre and post 1800.

The surprisingly sudden change in the pattern of fertility with wealth makes it hard to explain through economic variables which were all changing only slowly in England in these years, even though it is the period of the Industrial Revolution. This suggests

an alternative explanation in the form of some social or idealogical movement. One possibility, for example, is that the decline in fertility among the rich was a reaction among the economically successful to the widespread publicity afforded Thomas Malthus's *Essay on a Principle of Population*, first published 1798, but re-issued in five revised editions until the author's death in 1834. It is generally believed that public discussion of birth control in England dated only from the late nineteenth century. It was only in 1876 that Charles Bradlaugh and Annie Besant were prosecuted for republishing Charles Knowlton's pamphlet advocating birth control, *The Fruits of Philosophy*. But the evidence here suggests that there had to be some diffusion of contraceptive practices much earlier than this.

However, interestingly, we would expect such a social or intellectual movement to be associated with occupations or professions more than with incomes. However fertility fell as much among rich farmers in our sample as it did in more urban and professional occupations such as physicians, schoolmaster, clerks, and engineers. Even if we include our 7 occupational indicators in the regression, along with the log of asset income, differentiating pre and post 1800, there is still a sharp change in the association between income and fertility after 1800. Before occupations do not have differential fertility, once we control for asset incomes. After the slope on asset income fall to one fith of its previous level, and occupations remain insignificant predictors of net fertility.

The source of this remarkable change in fertility behavior around 1800 thus remains largely unidentified. Aggregate fertility declined in France long before anywhere else in Europe. Fertility

regimes within differed here by locality to a far greater extent than they did in England (The coefficient of variation in the index of marital fertility for France is 4 to 6 times that of England and Wales for the 19th century).[4] One of the authors, Cummins, has recently analysed the wealth fertility relationship for the period of transition in France (marriages formed 1748-1819). Demographic data from the *Enquete Henry* was linked to wealth at death data from the *Tables des Succsessions et Absensces* for four villages in the nineteenth century. Cummins shows a strong positive association between assets and wealth for villages where aggregate fertility levels were high.[5] Where fertility was declining, the wealth fertility relationship switched from positive to sharply negative.

As with England, these results show that wealth had a large positive effect on reproductive success in the pre-transitional era and fertility limitation by the top wealth category precedes aggregate fertility decline. Thus the transformation witnessed here for England seems likely part of a general transformation occurring in the switch from pre-industrial to modern fertility regimes. The French Fertility transition, however, occurred in the absence of any significant structural change in the economy and with income per capita levels significantly below those of England. Cummins' research suggests that movements in economic inequality and relative incomes may have a relationship with the onset of fertility decline.

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[4] At the county and *department* level.

[5] The result holds for both 'gross' and 'net' fertility (which takes child mortality into account).

Conclusion

While there is still much work to be done on the precise mechanisms and causes, we demonstrate above that pre-industrial fertility patterns did not survive unchanged in England until marriages of the 1870s as has been conventionally believed. Instead there was an important and rapid change in fertility patterns by wealth for marriages formed after 1800. Up until then the richest English men were producing 5 surviving children at a time when men in general produced only 2.5 surviving children. Within a generation the fertility of the rich fell to be no greater than, and perhaps less, that of the general population. A Demographic Revolution thus accompanied fairly closely the Industrial Revolution. Now united temporally, the two events may also be more plausibly linked causally.

Appendix – imputing missing values

In forming the data base of fertility, wealth at death and date of birth we had to assign values in a number of cases where data was missing: dates of birth, area of land holding, numbers of children (where only a partial count was given).

Where we cannot locate the information in parish registers or the census we assign each testator a date of birth and marriage date through the following means.

1. Ages and marriage dates 1500-1858

For these years we have the following information from parish records on birth dates, marriage dates, and age at first child.

Table A.1: Birth Information

Group	N	Birth date also N
Birth date	661	-
Marriage date	639	233
Age at first child	689	259
At least one of above	1,281	-

This reveals that the average age at marriage was 28, and average age at the birth of the first child 29.1. Using the cases where we could assign age at death years since birth, years since first marriage plus 28, or years since first birth plus 29.1 with some experimentation the following regression was found to be the best fit for age:

AGE = 9.42 + 0.0264DEC+1.174N +6.92DCHILD>21 - 9.625DCHILD<21 + 5.62DGRANDCHILD – 6.52DSINGLE + 5.73DWIDOWER – 6.81DPARENT + 6.05*DNEPH

$n = 1,111$, $R^2 = 0.495$

where DEC = birth decade (1520-1820)
N = number of surviving children
DCHILD>21 = indicator for at least one child known to be more than 21
DCHILD<21 = indicator for at least one child known to be less than 21
DGRANDCHILD = indicator for at least one known grandchild
DSINGLE = indicator for testator never married
DWIDOWER = indicator for testator widower
DPARENT = indicator for at least one parent known to be alive
DNEPH = indicator for a living niece or nephew

2. Ages and marriage dates 1846-1914

Post 1846 we sometimes collected more limited data on relatives and children's ages, in which we estimated missing ages from the regression

AGE = 62.37 + 0.08D1870 + 1.15D1880 + 0.79D1890 + 3.00D1900 + 3.20D1910 + 0.36N – 0.79DSINGLE + 9.11DWIDOWER

$n = 1{,}497$, $R^2 = 0.11$

where D1870, …D1910 are indicator variables for the death decades 1870-9 to 1910-9.

Land Areas, 1500-1858

While land was bequeathed in 2,108 of the wills in our sample, in only 534 cases, one in four, was the area of the land indicated. To infer the area in the other 1,574 cases we estimated for cases where area was indicated, that area as a function of other features of the will. For wills pre 1860 where we collected information on monetary bequests this was the number of houses bequeathed, the number of additional parishes the land was described as lying in, the total amount of cash and goods bequeathed, an indicator for the literacy of the testator, an indicator for whether the testator lived in a town, an indicator of whether the person engaged in farming, and indicators for each occupational group. The functional form that best fit the observed cases was chosen by experiment. Thus the estimated expression was

$$\log(AREA) = a + b_1 HOUSE1 + b_2 HOUSE2 + b_3 HOUSE3 + b_4 MOREPAR + b_3 BEQROOT + b_4 DLIT + b_5 DLITUNKNOWN + b_6 DTOWN + b_7 FARMER + \sum_i c_i OCCUP_i + e$$

where HOUSE1 was an indicator set to one if one house was bequeathed, HOUSE2 an indicator for two houses, HOUSE3 an indicator for three or more houses, MOREPAR an indicator for land left in more than one parish, BEQROOT the square root of the value of cash and stock bequeathed, DLIT an indictor for a literate testator, DLITUNKNOWN an indicator for someone whose literacy is unknown, DTOWN an indicator for a town dweller, DFARMER an indicator for someone engaged in farming, and $OCCUP_i$ indicators for the six occupational groups

defined above other than laborers. DFARMER was set to one if the testator left farm animals or grain in the will, or left farm implements. There were 408 observations with this complete information, and the R^2 of this regression was 0.52.

To normalize for changes in the price level over the years 1585 -1836 the "BEQROOT" variable in the above equation was constructed using the actual cash bequests in the will normalized by the average price level in each of the decades 1580-9, 1590-9, 1600-9, 1610-9, 1620-9 and 1630-9. To this was added the value of the stock left calculated using a standard set of values normalized to the 1630s: horses £5, cattle £4, sheep £0.5, pigs £2, wheat (bu.) £0.21, barley/malt (bu.) £0.10, oats (bu.) £0.07, peas/beans (bu.) £0.12, silver spoons £0.375, gold rings £1.

Land Areas (1846-1914)

Where we did not collect monetary bequests we estimated areas from the regression

$$LN(AREA) = a + b_1 PAR2 + b_2 PAR3 + b_3 SQRTDUTY + \sum c_i \, OCCUP_i + e$$

PAR2 was an indicator for land in two parishes, PAR3 and indicator for land in three or more parishes, SQRTDUTY the square root of the real value of the personalty estimated in probating the will. There were 173 observations with which to estimate the parameters of this regression, and the R^2 was 0.38.

Real Estate Value (1880-1914)

In some cases we get no information of the real estate in the will , such as when the testator simply leaves all their property to one recipient without specifying the details. In such cases we could still estimate the total value of the real estate from the characteristics of the testator and the probate estimate of personalty. This real estate value, however, is truncated at 0. So we use a Tobit estimate with a lower bound of 0. Where we have probate estimates of the (net) personalty after 1880 the equation estimated was

$$REAL = -162 + 0.273PROBATE + 1069DLON - 225DTOWN$$

$$n = 333, \text{ pseudo } R^2 = .006$$

REAL is the value of real estate (in 1630s prices), PROBATE the personalty (in 1630s prices), and DLON, DTOWN indicators for residence in London or another town. This implies that for testators outside London or a town after 1880, the expected value of real estate is 0 until the probate value of the will is £593 (in 1630s prices). Though REAL is highly significantly associated with PROBATE, as can be seen the Pseudo R^2 is very low. That is, the amount of the variation in REAL that we can explain with the equation is very low.

Real Estate Value (1750-1880)

For 1750-1880 we have estimates of the probate value of the estate, but in terms of tax bands that the value falls within. For this period also occupations were significantly linked to real estate. The predictive Tobit estimation was thus,

REAL = -332 + 0.079DUTY + 308DLON - 273DTOWN + 72STAT1 + 268STAT2 + 309STAT3 + 331STAT4 + 303STAT5 – 65STAT6 + 802STAT7

$n = 1{,}804$, pseudo $R^2 = .004$

DUTY is the maximum of the tax band the personalty fell within (in 1630s prices), and DSTAT1,…DSTAT7 indicators for social status. This implies that for testators outside London or a town before 1880, the expected value of real estate is always positive for gentry, but only positive for other occupations when the duty estimation rises above a certain minimum. Again the Pseudo R^2 is very low.

The table below shows the shares of real estate versus personalty in the total value of the bequest where we have complete information on each element. Though we can estimate real estate values only very poorly from the probate or duty value, fortunately over time real estate was becoming less and less important as a share of bequests. Thus even those wills where we have only the personalty values directly should give a reasonable guide to the total value of the bequest.

Probate Value (1500-1858)

Before 1858 there are many cases where we have no direct information on the value of the personalty from the probate or the duty declaration. In these cases we estimate the value of the personalty from the monetary gifts and goods bequeathed in the

Table A2: Share of Different Elements in the Total Bequest

Period	Share Real Estate (probate value)	Share Real Estate (duty value)	Share Cash and goods (probate value)
1750-1880	-	0.35	0.28
1880-1914	0.21	-	-

will, using the 255 cases where we have both the monetary and goods bequests and the probated value. The only feature of the will that was a good predictor of the probate value was the cash bequeathed within the will. Thus

$$\text{PROBATE} = 40 + 1.60\text{CASH}$$

$$n = 255,\ R^2 = 0.23$$

where CASH was the real value of monetary gifts and goods bequeathed within the will.

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