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FERTILITY TRENDS, EXCESS MORTALITY, AND THE GREAT IRISH FAMINE

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INTRODUCTION

Over the century preceding the Great Famine of 1845–1849, Ireland¹ experienced a rate of population growth unparalleled anywhere else in western Europe. The Famine set in train a population decline that was to last for another century and have a profound effect on subsequent economic and social trends. The crisis, probably Europe's gravest in the 19th century, has prompted much useful research into the nature of the prefamine economy and the short-term demographic consequences of the potato failure itself. The dependence of the poor on the potato in 1845 is clear: by then perhaps 3 million out of a population of 8.5 million relied on it almost exclusively for food, and millions more consumed amounts difficult to imagine today (Bourke 1968). The inevitability of crisis in the event of a three-year near-total shortfall is thus not in doubt. Controversy continues, however, about issues such as the prefamine reliability of the potato and its role in promoting population growth; the efficacy of relief policy from late 1846 on, when excess mortality became significant; and the extent to which the potato blight accelerated rather than initiated the dramatic long-term shifts in population and agriculture (Crotty 1966; Walsh 1970; Mokyr 1980b; Connell 1950). The definitive economic and social history of the Famine waits to be written, but Edwards and Williams (1956) and Woodham-Smith (1962) provide readable accounts of the Famine period, and Cousens (1960) and Mokyr (1980a, 1983) represent the vanguard of associated economic–demographic research.

Calculating the human toll of the potato blight holds a macabre fascination for historians. Estimates vary from 0.5 million (Green 1956:126; Daly 1981:20–21) to 1.5 million (Flinn 1977:421). Methods of estimation range from sheer guesswork to quantitative approaches. Among recent tallies of those who perished, the best known are by Cousens (1960) and Mokyr (1980a), both of whom proceeded from counterfactual calculations of normal population growth without the Famine. Cousens produced estimates of excess mortality on a regional basis and obtained a figure of 800,000 for Famine-related deaths. Mokyr pointed out some flaws in this approach and obtained estimates ranging from 1 million to 1.5 million.

Population growth is a function of three main components—mortality, fertility, and emigration. Reliable estimates of the first two—non-crisis mortality and fertility—are difficult to produce for Ireland, given the nature of available data.² The third component—emigration—is especially important in Irish demographic history. Here Adams's (1932/1967) detailed analysis of pre-Famine emigration to North America remains indispensable. Using ship passenger lists, Ó Gráda (1983) showed how a more detailed demographic profile of these emigrants can be established. The period was also one of substantial exodus from Ireland to Great Britain,³ however, and little reliable information exists on the volume and demographic characteristics of this flow.⁴

Once "normal" vital and emigration rates have been obtained, excess mortality can be estimated as a residual. But although establishing the numerical toll of the Famine is an important task, an analysis of its impact by region and by age and sex is of particular demographic interest. Cousens (1960) and Mokyr (1980a) examined the regional variation of excess mortality, but the incidence across age groups is still undetermined.⁵ Other studies have shown that mortality crises affect demographic groups differently, so to assume equal incidence across the life cycle is not persuasive. The Black Death, for instance, is commonly thought to have claimed more males and more young people (Hollingsworth and Hollingsworth 1971). Smallpox epidemics have had a greater impact on the young, whereas cholera outbreaks are more severe on the old. Goubert's work on the Beauvaisis suggests that the elderly were disproportionately affected by subsistence crises there in the 17th century (Das Gupta 1981; Dechene and Robert 1981; Goubert 1968).

It is therefore of interest to determine which age groups suffered most during the Irish Famine, and consequently a major aim of this paper is to estimate age-specific death rates in that period. We will also investigate the relative intensity of the excess mortality, comparing males and females. The basic approach is to use the 1821 and 1841 Irish census data, appropriately corrected, in conjunction with emigration statistics to obtain mortality and fertility estimates for the pre-Famine period. These estimates provide the basis for projecting the 1841 population forward to 1851, making allowance for emigration. Conceptually the method is straightforward; it is close in spirit to Wrigley and Schofield (1981:ch. 7 and appendix 15) and Mokyr (1980a). It pays more attention than the former, however, to the size and composition of the migration flow and is forced to rely more heavily on census data. Our approach differs from Mokyr's in that it does not assume a stable population and presents a more detailed analysis of the Famine mortality.

In calculating how excess deaths during the Great Famine were distributed by age and sex, new estimates of the trend in fertility are generated as a joint product. This new evidence, though tentative, indicates that birth rates were declining before the Famine, and the birth-rate estimates are corroborated using a technique proposed by Coale, Hill, and Trussell (1975). Our analysis also shows that the normal rates of mortality in pre-Famine Ireland were similar to, though somewhat higher than, those prevailing in England during the same period. These findings mark a contribution to Irish economic and population history, but it is hoped that they are of wider demographic interest, since so little material exists on the effects of famine on mortality and fertility.

The layout of the paper is as follows. In the following section some problems posed by the 1841 census returns are discussed. The data suffer, in particular, from extreme age-heaping at the decennial ages, which we corrected for. Next we present an analysis of another element in the calculations, Irish emigration for the 30-year period 1821–1851. Then the adjusted age data and the estimates of emigration by age and sex are combined to produce new estimates of pre-Famine mortality and fertility rates. These estimates are of considerable historiographical interest in themselves and are required to estimate famine mortality. Estimates, for each sex, of the age-specific mortality rates experienced during the Famine period are obtained next. The final section provides a summary of the paper.

AGE-HEAPING AND OTHER PROBLEMS

Censuses were taken in Ireland at 10-year intervals beginning in 1821 (Vaughan and Fitzpatrick 1978).⁶ The 1821 census recorded the total population in 5-year age groups up to age 20 and in 10-year age groups thereafter. The 1831 census contained

Table 1.—Myers Blended Index for males in Ireland, 1841 and 1851, and for total population in Philippines, 1960

Terminal digit of age	Ireland (males)		Philippines (total)
	1841	1851	1960
0	25.73	27.77	16.06
1	5.43	5.07	7.22
2	8.92	8.73	10.00
3	6.73	6.18	8.47
4	8.76	8.34	8.35
5	11.94	12.45	12.72
6	10.37	10.15	8.58
7	6.92	6.50	8.86
8	9.86	9.70	11.26
9	5.74	5.11	8.49
Summary preference index	18.04	20.37	10.04

no information on age structure and is generally believed to overestimate the actual population (but see Lee 1981). The 1841 census (Great Britain 1843) was the first to report numbers for each age and sex, but even a casual examination of the data reveals massive age-heaping⁷ (Lee 1968; Vaughan and Fitzpatrick 1978:75–77; Mokyr and Ó Gráda 1982). The 1851 census figures (Great Britain 1856) suffer from the same problem. Since these censuses constitute the main building blocks of our analysis, they must be adjusted to offset age-heaping. In table 1 a convenient measure of the nature and extent of age-heaping, the Myers Blended Index (Myers 1940), is applied to the Irish male population in 1841 and 1851. With no age preference, the value of the index for each digit would be 10 percent. The extent of age-heaping in a population is summarized by computing one-half the sum of the absolute deviations from 10 percent. This index, the summary preference index, is 0 for a population with no age-heaping. Some appreciation of the extent of age-heaping reflected in these figures may be gained from noting that the 1960 population of the Philippines, considered to exhibit severe age-heaping, produces a summary preference index of only about half that of these Irish populations.

We were unable to establish definitely whether age-heaping was associated with consistent understatement or overstatement of ages for particular age ranges by one or both sexes. Nevertheless, though the age-shifting and age-heaping effects could not be unraveled without a knowledge of the “true” underlying age distribution, evidence of certain biases was detected, which will be mentioned later in the paper. The 1841 Census Commissioners noted the extensive age-heaping in the recorded figures (Lee 1968:289) and produced their own smoothed age distribution (Great Britain 1843:488–489). No indication of how these smoothed or “real” numbers were obtained was given, though it seems a graphical procedure was used. The smoothed numbers in this study are based on a more objective technique. Hardy’s wave-cutting formula (Benjamin and Haycocks 1970:248) was applied to the raw data first, and the numbers were then smoothed further using the Karup–King formula (Shryock and Siegel 1973; for details, see Boyle and Ó Gráda 1983). Table 2 contrasts the raw age data from the census with the smoothed age distribution used in this paper. For ages 0–10, we used the smoothed age distribution produced by the

Table 2.—Reported and smoothed age distribution, males, 1841 Irish census

Age	Reported in census	Smoothed	Age	Reported in census	Smoothed	Age	Reported in census	Smoothed
0	103479	142481.	40	128841	40744.	80	11158	2713.
1	81042	129528.	41	18374	39324.	81	1434	2578.
2	117753	117753.	42	32504	37982.	82	1700	2451.
3	110517	111550.	43	26624	36715.	83	925	2283.
4	110936	110550.	44	25599	35526.	84	1857	2031.
5	109883	109980.	45	46023	34413.	85	1096	1695.
6	110616	109750.	46	28115	33377.	86	1098	1343.
7	112742	109330.	47	17983	32418.	87	655	983.
8	112043	108780.	48	28359	31536.	88	722	628.
9	99570	107780.	49	11976	30731.	89	376	397.
10	112351	106410.	50	100200	29913	90	1197	0
11	86021	105382.	51	10020	29008.	91	228	0
12	120258	104429.	52	23906	28069.	92	227	0
13	93238	103481.	53	13700	27096.	93	177	0
14	107008	102399.	54	19314	26088.	94	177	0
15	90224	100921.	55	32262	25046.	95	213	0
16	97480	98761.	56	25030	23970.	96	212	0
17	78561	96077.	57	11705	22860.	97	169	0
18	96194	92663.	58	16392	21715.	98	169	0
19	69578	88339.	59	6917	20536.	99	153	0
20	109319	83440.	60	80027	19287.			
21	63063	78668.	61	7197	18035.			
22	72647	74383.	62	9997	16849.			
23	55225	70584.	63	11080	15728.			
24	72577	67283.	64	11218	14673.			
25	72665	64449.	65	14516	13683.			
26	70510	62112.	66	11853	12758.			
27	51314	60262.	67	7100	11898.			
28	68066	58898.	68	7826	11104.			
29	30942	58022.	69	3559	10375.			
30	128215	56392.	70	27964	9372.			
31	23502	53839.	71	2844	8148.			
32	48695	51518.	72	5840	7070.			
33	30004	49428.	73	3587	6140.			
34	39539	47570.	74	4352	5357.			
35	61629	45934.	75	6524	4720.			
36	49297	44548.	76	4658	4231.			
37	23721	43385.	77	2676	3888.			
38	35176	42453.	78	3411	3692.			
39	15300	41753.	79	1467	3644.			

Note: See text for smoothing procedure.

Census Commissioners, since our smoothing technique loses 11 observations at the extremities of the distribution.

Wrigley and Schofield (1981), in their recent extensive analysis of English population history, indicated that the number of infant children aged 0–4 was understated in the 1841 Census of Britain. Several authors, notably Tucker (1970), have also commented on the serious undercounting of children in the 0–2 age group in the 1841 Irish census. The “real” figures prepared by the Census Commissioners correct for this. These figures are used in our analysis, but the birth-rate calculations presented later indicate how a possible cross-check can be obtained.

A similar analysis of the female population produced even more acute age-

Table 3.—Summary preference indices of age-heaping

Year or period	Category	Summary preference index
1841	Males in population	18.04
	Females in population	20.00
1851	Males in population	20.37
	Females in population	22.43
1830–1841	Male deaths	24.05
	Female deaths	28.12

heaping. The 1841 census population figures for females were smoothed and adjusted in the same way as for males. For ages 11 and above, successive applications of Hardy's smoothing formula and the Karup–King procedure produced a smoothed age profile.

The 1841 census also contained information on the deaths that took place during the 10 years prior to the census. Since the information on deaths relied on the memory of survivors in 1841, the totals underestimate pre-Famine mortality. The recorded ages of death in these tables indicate acute age-heaping (see table 3). The severe bias in the numbers of reported deaths and the serious distortions introduced by extreme age-heaping mean that these figures are unreliable measures of the mortality levels in Ireland during the period leading up to the 1841 census.

EMIGRATION FROM IRELAND, 1821–1851

The estimation of birth and death rates before the Famine is considerably complicated by the presence of emigration. The numbers leaving Ireland rose dramatically during the Famine period and remained a dominant feature of Irish demographic history for the next century. It is perhaps insufficiently realized, however, that the outflow before 1845 was also significant. Indeed, Ireland before 1845 produced more long-distance emigrants relative to the home population than any other European nation. Though the majority of Irish emigrants went to North America, emigration to Britain was also important.⁸ It is convenient to deal with these two flows separately. We use the term North America to describe what is now Canada and the United States.

Emigration to North America From Ireland

Estimates of the annual number of emigrants from Ireland to North America between 1825 and 1845 are provided by Adams (1932/1967:413–415). For purposes of the present paper, it is assumed that emigration to North America for the 1821–1824 period averaged 13,000 annually. This is similar to the figure of 13,719 reported by Adams for 1825 (1932/1967:413). We relied on the 1851 census returns for emigration from Ireland to North America during the period 1846–1851. These figures are reproduced in Vaughan and Fitzpatrick (1978:260). Our estimates of numbers emigrating in each year are given in table A1 of the Appendix.

Emigrant age–sex composition may be estimated from samples of ships' passenger lists (Ó Gráda 1983). The lists show that during the 1820s the ratio of males to

females was 60:40; it dropped thereafter to 55:45. Most of the emigrants were in the 20–35 age group. Age-heaping is again a serious problem, being of the same order of magnitude as in the 1841 census (Mokyr and Ó Gráda 1982); it was corrected for as described earlier. The adjusted age structure was converted to percentages, and the resulting percentages were applied to the total annual number of emigrants, treating each sex separately to obtain the age–sex composition of emigrants for a given year.

Emigration to Britain From Ireland, 1821–1851

As mentioned earlier, solid quantitative evidence on Irish emigration to Britain before the Famine is unavailable. The approach adopted here is to produce a range of annual estimates consistent with contemporary evidence and to use the census information on the stock of Irish-born in Britain as a cross-check. Rough estimates of emigration for different subperiods are produced by Adams (1932/1967:123, 141–142, 175–176), Redford (1964:156–158), and Flinn (1977, especially pp. 302–303, 455–457). The range of estimates of the year-by-year totals given in table A1 is based on such sources. Three scenarios were developed to gauge the sensitivity of the final results to this emigration. The pattern described by Basis C is judged to be the most plausible⁹ of the three (for details, see Boyle and Ó Gráda 1983:11–12). The age and sex distribution of the emigrants can be inferred from the 1841 British census. The census reports 419,256 Irish-born people living in Britain at that date, of whom 52 percent were male (Great Britain 1843:X). Ten years later, the corresponding number was 733,866: 195,538 of those were under 20, and the figures exclude the British-born children of Irish parents (Great Britain 1853). The numbers, if correct, imply that Irish women and children formed a higher proportion of emigrants to Britain than to North America.¹⁰ For Basis C, the emigrants were assumed to be 52 percent male before 1841 and a slightly higher percentage thereafter. It was assumed that emigrants from Ireland to Great Britain under Basis C had the same age distribution as the Irish population resident in Ireland at the time of emigration. Such an assumption gives an age distribution for 1851 Irish-born British residents that is consistent with the census.

ESTIMATING PRE-FAMINE MORTALITY

In this section, the population figures given in the 1841 and 1821 Irish censuses, taken in conjunction with the assumed emigration patterns described in the previous section, are used to generate estimates of the mortality rates prevailing in Ireland during these two decades. It is assumed that mortality rates were approximately constant¹¹ for the period and that these rates represent the “normal” level of mortality for the ensuing 10 years.

The basic procedure used is as follows. The 1841 census was projected backwards on an assumed mortality basis, making due allowance for the year-by-year incidence and composition of emigrants. The projected 1821 population was then compared with the actual 1821 population and the parameters of the mortality law adjusted until good agreement was obtained. At the same time, constraints had to be imposed on the mortality law to obtain rates that were “reasonable.”

The method eventually adopted was obtained after considerable experimentation. As a starting point in representing age-specific mortality rates up to 35, English Life Table III (*Journal of the Institute of Actuaries* 1892) was used. This table was computed on the basis of English mortality experience during the period 1838–1854. Like Wrigley and Schofield (1981:708–711), we found this a good representation to age 35. Above this age a heavier mortality was called for, and a Gompertz law was assumed to apply to age 80 (Reddington 1969; Daw 1961) and a fifth-degree spline to

Table 4.—Reported and projected population by age, Ireland 1821

Age range	Reported	Projected ^a
0-14	2,898,274	2,898,813
15-39	2,804,527	2,800,344
40-59	932,802	932,210
Total	6,635,603	6,631,367

^a Aggregates of single year age estimates for each sex obtained by backward projection from 1841; see text for details of method.

the remainder. These components were spliced together to provide a smooth fit. The resulting mortality table was used as a standard for the Brass logit model (Boyle and Ó Gráda 1983).¹² For Basis C the results shown in table 4 were obtained.¹³

The 1821 census results provide no age-sex distribution; only the total number of males (3.34 million) and females (3.46 million) and the total for both sexes in broad age groups are given. The optimization procedure projected the male and female populations separately for each age and combined to obtain the aggregate figures in table 4. The requirement that the total projected male population equal the recorded male population in 1821 was included as a constraint, and similarly for the total female population. This approach yields the estimates of the male and female age-specific mortality rates reported in table A2 of the Appendix, which also shows the corresponding life tables and expectation of life. Two aspects of the results are worth noting: first, male mortality rates for the age range 10-40 are lighter than those for females, and second, the overall levels do not differ much from the levels given by the English Life Table (ELT) III (*Journal of the Institute of Actuaries* 1892). Table A3 compares the expectation of life derived from our estimate of pre-Famine Irish mortality with those of ELT III. Note that for ages above 35, the English Life Table implies somewhat higher mortality. In fact, Wrigley and Schofield (1981:110) provided evidence that the ELT III represents lower mortality levels than the actual experience on which it was based.

The nature of the data precludes a precise measure of infant mortality. The infant mortality rates depend strongly on the initial selection of the corresponding English Life Tables. The birth rates below are based, however, on the same assumption concerning infant mortality, with the result that any errors in the latter are absorbed in the former. For example, if the estimated infant mortality rates are too low (compare Mokyr 1983:ch. 2), an appropriate reduction in the calculated birth rate means that the "correct" number of survivors is still obtained.

ESTIMATION OF PRE-FAMINE BIRTH RATES IN IRELAND

The mortality estimates derived above will now be used to estimate the number of births in each year from 1821 to 1841. Assuming approximately constant mortality rates¹⁴ means that the numbers alive at each age from 1 to 20 years in 1841 can be projected backwards to the year of birth. This procedure is carried out separately for each sex, with allowance for the relevant emigrants by adding them back in each

Table 5.—Estimated crude birth rate, Ireland and England, 1822–1841

Year	Ireland	England ^a	Year	Ireland	England ^a
1822	42.3	41.9	1832	40.4	35.2
1823	42.1	40.8	1833	40.0	36.8
1824	41.7	39.9	1834	39.5	36.0
1825	41.3	39.6	1835	38.8	35.6
1826	41.0	39.5	1836	37.9	35.8
1827	41.0	37.3	1837	37.1	35.3
1828	40.9	38.5	1838	36.3	35.2
1829	40.9	35.7	1839	36.5	36.3
1830	40.8	35.6	1840	37.7	36.1
1831	40.6	35.2	1841	36.4	36.0

^a Wrigley and Schofield (1981, page 534).

year. In this way, an estimate of the number of male and female infants born in each year can be obtained.

The birth rates thus derived provide some interesting comparisons with the existing literature. Mokyr (1980a) calculated a crude birth rate of 39 per 1,000 over the period. That estimate is consistent with ours, though in addition, we find that the birth rate declined over the period. This decline is robust with respect to our assumption about emigration to Britain. It is sometimes suggested that birth rates were dropping during this period (see Mokyr and Ó Gráda 1984), but as far as we know, this paper presents the first tentative numerical estimates of the phenomenon. Perhaps a decreasing marriage rate offers a partial explanation (Ó Gráda 1982), but this interesting question remains open.¹⁵

The results obtained when the 1841 population from ages 1 to 20 are projected backwards to year of birth are presented in table 5. The crude birth rates decline from around 42 per 1,000 to about 36.5 per 1,000. These estimates for the Irish birth rate are similar to those obtained by Wrigley and Schofield (1981) for England during the same period, using a much more reliable data base. The technique employed here enables us to estimate the entire age–sex composition of the Irish population for each year from 1821 to 1841. By relating the total number of births each year to the female population aged 15–44, estimates of the general fertility rates over the period can be obtained. Although the results are not presented in this paper, general fertility rates declined over the period as well.

Two independent procedures offer a cross-check on our results. First, the male/female ratio at birth can be computed each year, and we have strong prior beliefs concerning the size of this ratio on general demographic grounds. Second, we can use the Coale–Hill–Trussell (1975) technique as a consistency check on the birth rate in 1841. The ratio of male to female births is quite plausible (around 1.05) from 1826 onward, though for the first four years, the number of female births exceeds the number of male births. We suspect that this anomalous result is due to certain biases in the 1841 census that remain even after the smoothing of the age groups.¹⁶

Alternative estimates of the Irish birth rate in 1841 can be obtained from the approach developed by Coale, Hill, and Trussell. The census figures give the number of children ever born by year of marriage (Great Britain 1843:486). Restricting the analysis to first marriages produces the figures shown in table 6.

Table 6.—First marriages by year of occurrence and number of children ever born, as reported in Census of Ireland, 1841

Year of marriage	Number of marriages	Number of children born to these marriages ^a
1830	38,358	148,340
1831	37,522	136,152
1832	38,009	126,173
1833	38,598	117,003
1834	41,112	110,880
1835	41,588	97,620
1836	39,002	77,637
1837	37,289	60,773
1838	41,866	52,240
1839	40,135	35,207
1840	34,603	15,421
1841 ^b	14,400	1,000

^a To Census date 1841^b Estimated

From these figures, the average parities for marriages of less than 5 years duration and those of between 5 and 10 years can be computed. Using the notation of Coale-Hill-Trussell, we obtain the following for the observed and calculated parities:

<i>Duration of Marriage</i>	<i>i</i>	<i>P_i</i>	\hat{P}_i	<i>R_i</i>
0–4 Years	1	1.098	1.083	1.014
5–9 Years	2	2.854	3.107	0.919

These estimates assume a singulate mean age at marriage of 25 and an age of 15 at which first marriages begin to occur.¹⁷ The ratio *R* should be approximately constant for both groups: the value for the range 0–4 has been taken as the more reliable, so 1.01 has been used in our calculations.

The first step in the birth-rate estimation is to multiply the standard age-specific marital fertility rates by 1.01 and apply the resulting rates to the numbers of married females in the 1841 Irish population. This yields 317,000 births for 1841, resulting in a birth rate of 38.3 per 1,000, which compares well with the figures given in table 5.

Some features of the mid-19th century Irish demographic context favor the use of this procedure. Researchers agree that illegitimacy was uncommon and birth control was insignificant (e.g., Connell 1968; Connolly 1979). On the other hand, the census data undoubtedly contain errors; but such errors plague any attempts at estimating birth rates from this material, and the Coale-Hill-Trussell method is more robust than most in handling them.

ESTIMATION OF MORTALITY AND FERTILITY DURING THE FAMINE PERIOD

The broad outlines of the approach used are similar in spirit to that employed by Mokyr (1980a), but it differs considerably in detail. The Irish population as estimated by the 1841 census and adjusted as described earlier is projected forward to 1851, with allowance for the actual emigration¹⁸ that occurred during the decade. By comparing the numbers obtained by this projection with the actual numbers given in the 1851 census, we can use an optimization procedure to estimate the mortality

levels prevailing during the decade. Our approach is somewhat more detailed than Mokyr's, since we carry out projections for each sex separately on an age-specific basis. We also use different technical procedures to obtain our results. It turns out to be particularly difficult to estimate the numbers of children aged 0–5 who perished during the Famine. We will explain why this is the case and outline the procedures used to handle this problem. To relate the mortality levels prevailing during the Famine to those that obtained during the previous two decades, we have expressed the Famine age-specific mortality rates as a function of the "normal" mortality rates prevailing before the Famine.

It is convenient to project the 1841 population for the 10-year period in two steps. First, we project it forward until mid-1846, assuming that normal mortality levels corresponding to those obtained above prevailed during this period. The emigration assumptions used are as described previously and shown in table A1. Separate projections were carried out for each sex on an age-specific basis. This produces estimates of the numbers alive and resident in Ireland, aged 5 and over, in 1846. To estimate numbers below age 5, we assumed that the general fertility rate during the period 1841–1846 was the average of the general fertility rates for the period 1837–1840. To obtain the number of births in each year, this rate was multiplied by the number of women in the 15–44 age group. It was assumed that male births exceeded female births by 5.2 percent. The procedure furnishes age-specific estimates of the numbers of each sex alive and resident in Ireland in mid-1846.

For the second half of the period, we assumed that the population was exposed to the full force of Famine conditions. For modeling purposes it was more convenient to represent the onset of the Famine as a discontinuous process starting in mid-1846. The 1846 population was projected forward until 1851 and compared with the population estimates obtained from the 1851 census, as adjusted for age-heaping using the technique described previously. In carrying out this projection, the age-specific emigration figures in table A1 were used. Two different approaches were used with regard to the mortality assumption. First, an optimization procedure was used to find the mortality table that gave the best fit between the 1851 population recorded in the census and the 1851 population obtained from our forward projection. Second, the 1846 population was projected forward by using the "normal" or pre-Famine level of mortality and actual emigration figures. The shortfall between these numbers and the actual 1851 census figures is attributable to the excess Famine deaths.

The first of the procedures just outlined must be broken down into two steps. First, the projected population aged 5 and over in 1851 is compared with the census population aged 5 and over in 1851, and mortality tables that give the best fit between these two populations are derived. Actual emigration during the Famine period is allowed for in these calculations. Second, we deal with children under age 5 in 1851, that is, children born during the Famine period. Conditions during the Famine period were anything but normal, and it would be inappropriate to assume that fertility levels remained at their pre-Famine levels. There is also a considerable degree of interdependence between the assumptions made regarding the birth rates during the Famine and the computed child mortality rates of these same children during that period. For example, if the Famine birth rates are overestimates, then the only way to project the number of these births during the period 1846–1851 and get the 1851 census numbers would be to overestimate the mortality rates that these children were exposed to during the 5-year projection period. The converse is also true. If the Famine birth-rate estimates are too low, then the computed child mortality rates will also be too low.

We investigated a number of solutions to the question of Famine-born children before selecting the approach described below. The assumptions underlying this approach are that (a) the age-specific mortality rates during the Famine years were stationary and (b) the fertility rate during each year of the Famine was proportional to the size of the population during that year and was a constant fraction of the pre-Famine level. These assumptions are plausible within the context of our overall approach. Recall that the census population figures and the emigration figures have been smoothed to iron out the effects of age-heaping. The underlying data are not accurate enough to pick up year-to-year fluctuations, so the assumptions of stationarity seem appropriate. The rationale behind the fertility rate assumption is that at the onset of the Famine, this rate dropped to a fraction of its pre-Famine level and remained at this level for the duration of the Famine.¹⁹ The actual births during each year also depended on the actual population base of women of child-bearing age during each year of the Famine. Estimates of the size of this cohort for each year are available from the computations described earlier.

To describe the actual procedure used to estimate both fertility and child mortality rates during the Famine, it is helpful to use some notation. Let

- $m = .512671$ = assumed fraction of total births that are male;
- B_{yy} = total number of births in year 18yy, assuming pre-Famine fertility,
- f = fraction of pre-Famine fertility experienced during the Famine;
- P_x^{51} = number of males aged x last birthday as recorded in the 1851 census after adjustment for age-heaping and undercounting.

With this notation, we can express the numbers of male births in each Famine year as follows: 1846, $mf B_{46}$; 1847, $mf B_{47}$; 1848, $mf B_{48}$; 1849, $mf B_{49}$; 1850, $mf B_{50}$. Note that the only unknown here is f . These births are then projected forward until 1851, allowing for actual emigration in such a way that the mortality table used produces the best fit between the projected 1851 population and the 1851 population recorded in the census. Thus, for example, the children born in 1846 would be aged 4 in 1851. The survivors of this cohort ($mf B_{46}$), after allowing for actual emigration and Famine mortality during the four-year period, would represent the projected population figure in 1851. This projected figure is then compared with the census figure of P_4^{51} , which we define as the “actual” population figure. This procedure was also carried out jointly for the female children born during the Famine.

The optimal fit was found by minimizing the sum of the squares between the actual population in 1851 and the projected population. The outcome of this procedure yields estimates of the actual age-specific mortality rates experienced during the Famine for Famine-born children as well as an estimate of the fertility reduction caused by the Famine. Using this procedure, we estimate that the effect of the Famine on the fertility rate was a reduction of the birth rate during the Famine to 75 percent of its pre-Famine level.

Chowdhury and Chen (1977) also found a significant drop in fertility during the two contemporary Bangladesh famines. These famines were due to a war in 1971 and severe flooding that gave rise to crop failure in 1974–1975. High-quality demographic data were available from a longitudinal vital registration data base for the Matlab Thana, a rural area 40 miles from the capital, Dacca. The pattern of the crude birth rates during the two famine periods is given in table 7: Our results demonstrate a similar reduction in the birth rate, although the 1975 drop in Bangladesh was even more pronounced than the drop in Ireland during 1846–1851.

Those births that did not take place because of the impact of the Famine have sometimes been labeled averted births (e.g., Mokyr 1980a). In the case of Ireland,

Table 7.—Estimated crude birth rate (CBR), Matlab region, Bangladesh, 1966–1975

Year	Abnormal condition	Crude Birth Rate per 1000	Year	Abnormal condition	Crude birth rate per 1000
1966	--	46.8	1971	War	44.5
1967	--	45.2	1972	--	41.8
1968	--	46.4	1973	--	47.8
1969	--	45.2	1974	Flooding ^a	40.1
1970	--	43.6	1975	Flooding ^a	27.6

Source: Chowdhury and Chen (1977).

^a Resulting in crop failure

our estimate is that the 25 percent drop in fertility levels during the Famine translates into 315,000 averted births.

With regard to the computation of Famine mortality, as noted above, our procedure provides estimates of age-specific mortality levels for each sex during the Famine period. It turns out that the mortality experience during the Famine can be approximated very closely in terms of pre-Famine mortality by means of a simple linear transformation of the age-specific death rates. For males the transformation for ages 5 and upward is

$$Q_x = 0.0065 + 1.98q_x,$$

where q_x is the precrisis age-specific death rate and Q_x is the corresponding death rate during the Famine. The transformation for females aged 5 and upward is

$$Q_x = 1.98q_x.$$

These two relations show that the effect of the Famine was approximately to double the pre-Famine rates. Table A4 summarizes some pertinent Famine mortality statistics. Because mortality rates approximately doubled at each age, the relative severity of the Famine was more pronounced where the rates were highest, that is, on the very young and the very old. Chowdhury and Chen (1977) observed a similar result for the Bangladesh famine. During the Irish Famine, age-specific death rates for the age range 10–45 were higher at each age for males, whereas for the pre-Famine period the reverse was true (cf. tables A2 and A4).

The more conventional and dramatic method of representing the impact of the Famine is to compute the number of excess deaths due to the Famine itself. To arrive at this number, we redid the population projection for the period 1846–1851 to make allowance for actual emigration and normal, precrisis mortality. The revised 1851 population represents our estimate of what the census figures would have been had the Famine not occurred. Note that we did not attempt to use “normal” emigration rates for the Famine period but used, instead, the actual rates experienced during the period 1846–1851. The results are summarized in table 8.

These results indicate that the total number of excess deaths during the Famine was about one million.²⁰ This number is fairly robust with respect to the emigration pattern employed (Basis A, B, or C). Under all three assumptions, more males died than females, but the difference is more pronounced under Basis C. For the Bangladesh Famine, Chowdhury and Chen (1977) reported more deaths among females in all age groups except infants.

Table 8.—Estimated loss to 1851 population of Ireland arising from excess deaths during famine years^a

Emigration assumption	Male	Female	Total
Basis A	505,000	476,000	981,000
Basis B	544,000	528,000	1,072,000
Basis C	511,000	474,000	985,000

^a Difference between projected and recorded population for 1851; see text for procedures.

Comparing the excess deaths with the average population during the period 1846–1851 reconfirms the vulnerability of the very young and the elderly. Table 9 gives the numbers of excess deaths for four age groups expressed as percentages of the average population in the age group during the Famine years. Note that 29 percent of the excess deaths occurred in the 0–4 age group, although this group represented only 13.5 percent of the average population during the period. The percentage of excess deaths for those over 60 was also relatively high compared with their fraction of the population. In relative terms, therefore, the fewest excess deaths took place among those aged 10–59. This group accounted for 68.5 percent of the average population and only about 40 percent of the excess deaths.

SUMMARY AND CONCLUSIONS

This paper has developed estimates of the age-specific mortality rates prevailing during the Great Irish Famine and has analyzed fertility trends during the 25 years before the Famine. Our calculations confirm that 1 million Irish people perished as a result of this disaster. This figure does not include the deaths among the 1.3 million emigrants who left Ireland during the Famine period. The Famine produced a significant drop in the fertility rate, and we estimate that more than 300,000 births did not take place as a result of the Famine. The effects were especially severe on the very young and the very old, a result echoed in the findings of demographic analyses of other famines.

Our procedure permits a reconstruction of the Irish population by age and sex during the period 1821–1841. In addition, it yields year-by-year estimates of the birth rate over this period. We estimate that the rate fell by about 14 percent, a result

Table 9.—Estimated excess deaths and average annual population during famine years, by age and sex

Age	Male				Female			
	Excess deaths		Average annual population		Excess deaths		Average annual population	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
0–4	146,000	29	508,000	14	139,000	29	491,000	13
5–9	95,000	18	471,000	12	92,000	20	455,000	12
10–59	204,000	40	2,526,000	68	191,000	40	2,659,000	69
60+	66,000	13	211,000	6	52,000	11	234,000	6
Total	511,000	100	3,716,000	100	474,000	100	3,839,000	100

robust to our assumptions regarding emigration. Economic historians have debated this issue, and we hope that our evidence, although preliminary, will be of assistance.

Our analysis also permits year-by-year reconstruction of Irish population totals for the period 1821–1851. Two years are of particular interest. Virtually all recent writers, with the notable exception of Lee (1981), have suggested that the 1831 census returns overestimated the actual population resident in Ireland at that date. Our reconstruction supports the validity of the 1831 census figure. We obtain a total of 7,847,000, which is in good agreement with the disputed²¹ census figure of 7,767,000. But perhaps the most interesting figure is the population total for the end of 1845, the highest ever achieved in Ireland. We estimate that the population on the eve of the Great Famine was 8,525,000.

Throughout the paper we have tried to highlight those areas in which the data are unreliable, unavailable, or distorted. We have tried to devise cross-checks for consistency and to test the sensitivity of the results to a range of assumptions. A case in point concerns the age–sex profile and volume of emigration to England, Scotland, and Wales. Additional work at the micro level would be helpful here. More solid evidence on Famine births would also be helpful. The parish registers we have sampled certainly provide a clue to trends, but we have only made a start in that respect.²² A much more comprehensive survey is needed to convey the national picture. It is hoped that the methodology developed here will prove useful as more accurate information becomes available. It may also help in tackling population history at a regional level.

NOTES

¹ In the context of the present paper, the term Ireland refers to the entire island, that is, the current geographical area occupied by the Republic of Ireland and Northern Ireland. Before 1921 the entire island was part of the United Kingdom of Great Britain and Ireland.

² Civil registration did not begin in Ireland until 1864, and parish registers, where they survive, contain less data than elsewhere. In particular, burial data are scarce. The techniques developed by the French school of demographic historians and by Wrigley and Schofield (1981) are therefore rarely applicable. Mokyr (1983:ch. 3) produced estimates of both the birth rate and marital fertility on the eve of the Famine and extrapolated from them. Though his results are plausible, the trend in fertility before the Famine remains a puzzle (Drake 1963; Lee 1968; Tucker 1970; Mokyr 1980a). The balance of opinion indicates a decline in the birth rate during the 1820s and 1830s, though this has by no means been conclusively demonstrated (Mokyr and Ó Gráda 1984).

³ We use the term Great Britain to refer to the current geographical area of Scotland, England, and Wales.

⁴ Emigration to Great Britain was, after all, *internal* migration within the United Kingdom, and the data currently available only permit indirect estimates of the volume and pattern of this emigration flow (see Mokyr 1980a).

⁵ There is literary evidence that certain age groups were especially vulnerable. At the height of the crisis in west Cork, it was reported that it was “the aged, who with the young—neglected, perhaps, amidst the widespread destitution—are almost without exception swollen and ripening for the grave” (MacArthur 1956:289).

⁶ Very useful summaries of Irish census data from 1821 onward are given by Vaughan and Fitzpatrick (1978).

⁷ The Census Commissioners (Great Britain 1843:xiv) were well aware of problems of this kind, since they allude to “the common anxiety of individuals to deceive others as well as themselves into the belief that they are younger than they really are.” (See also Wrigley and Schofield 1981:113.)

⁸ Emigration elsewhere was of minor significance in the pre-Famine period. In addition, the number of emigrants to Ireland was insignificant (Mokyr 1980a).

⁹ Table A1 displays the number of emigrants to Britain on a yearly basis from 1821 until 1851 under the three assumed bases. Basis B assumes a level number of emigrants for the period 1821–1841 and a level number for the decade 1841–1851. Basis C attempts to incorporate evidence on both the volume and year-by-year incidence of the migration flow and is judged the most plausible. The estimates for Basis A are higher than those for Basis C.

¹⁰ Admittedly these can suggest only broad outlines, but the available information is scanty. No age information is available on the 1841 Irish-born residents of Great Britain. For 1851 Irish-born residents of Great Britain, the sex composition is not recorded in the published census, but a sample of 1,352 Irish-born residents of Britain in 1851 (courtesy of Professor Michael Anderson of the University of Edinburgh) provides useful evidence on this point. Of the 1,352, 689 (51.6 percent) were male. More than 31 percent of the sample were under 20, a higher proportion than the share of the Irish-born under-20s in the total population (195,866, or 26.5 percent). This sample provides further evidence that the emigrants to Britain during the 1840s contained a relatively higher number of children and women than did the emigrants to North America.

¹¹ This approach is a refinement of that of Mokyr (1980a), who projected the total population backwards, using his own estimates of crude birth, death, and emigration rates.

¹² An optimization procedure was used to find the Brass parameters α and β that minimized the squared deviation between the population figures reported in the 1821 census and those obtained by projecting the 1841 population backwards to 1821. The optimal Brass parameters had the following values:

	α	β
Males	-0.04	0.98
Females	0.04	1.04

Details of the Brass logit model are given in Carrier and Hobcraft (1971).

¹³ Certain adjustments were made to the actual recorded and projected population figures to obtain the numbers in table 4. By analogy with the 1841 census, we would expect the number of infants to be undercounted. To correct for this, the 0-4 age group given in the 1821 census has been increased by 100,000. There is also evidence of overstatement of age, which is not corrected by our smoothing technique. To correct for this, 50,000 have been transferred from the projected population total for the 40-59 age group to the projected 15-39 age group. This last adjustment is in line with the findings of Wrigley and Schofield (1981:104-108; see also Lee and Lam 1983). Though the direction of these adjustments is consistent with other research in this area, we have no direct method of estimating their size. Indirect support is provided by the numbers in table 4, which show a good fit between the actual and projected 1821 populations.

¹⁴ In particular, we have assumed that infant mortality was approximately constant over the 1821-1841 period. A significant rise in infant mortality could mean that there was no decline in the actual birth rate, but the admittedly scant evidence available (e.g., see Ó Gráda 1982) does not point in that direction.

¹⁵ The possibility that the fertility decline was due to the smoothing procedure was checked as follows. Raw unadjusted age data from the 1841 census were used to generate an alternative time series of birth rates. Even though this series fluctuated strongly, there was evidence of a downward trend. In addition, a five-year moving average birth rate was calculated for 1824-1839 from this alternative time series, thus removing the impact of the large numbers reported as aged 20 in the 1841 census. The trend was still downward.

¹⁶ The "incorrect" sex ratio at birth for 1821-1825 may be accounted for as follows. Suppose that females above age 20 have a greater tendency to record their age as exactly 20 than those below age 20, so age-heaping at age 20 is not symmetrical. Our smoothing technique will not correct for this bias. A simple example may illustrate this point. Consider five female ages: 14, 17, 20, 23, and 26. The actual and recorded numbers are given below for a situation in which this bias is present.

Age	Actual Number in Population	Recorded Number in Census
14	220	220
17	210	190
20	200	260
23	190	150
26	170	170

The 260 aged 20 in the census include 40 aged 23 and 20 aged 17. If we smooth these figures, using a three-year moving average, the smoothed age distributions become 223.3 for age 17, 200 for age 20, and 193.3 for age 23. Comparing the smoothed age distribution with the true distribution, we see that the combined effect of the smoothing technique and the "untruthful" ladies leads to overrepresentation in the 15-20 age cohort. If this group is projected backwards, these females will be overrepresented at birth. The same effect on the sex ratio at birth would result if males in their late teens tended to record their age as 20 to a greater extent than would be expected by symmetric age-heaping (cf. Lee and Lam 1983).

¹⁷ The assumed SMAM is a year less than Mokyr's estimate for 1841 (Mokyr 1983:35): the small difference, although hardly affecting the outcome, reflects the likelihood of some adjustment in marriage age over the period.

¹⁸ For most of this section, the discussion will assume that Basis C estimates are used. The procedure is general, however.

¹⁹ Mokyr (1980a:247) suggested that the decline in birth rates was particularly severe in 1846, 1847, and 1849. Without additional accurate data at the micro level, however, it is difficult to put an estimate on the magnitude of these fluctuations.

²⁰ Our calculations thus support Mokyr against revisionist accounts (e.g., Daly 1981:20–21), which deemphasize the demographic effect of the Famine.

²¹ Lee (1981) challenged independently the conventional appraisal of the 1831 census. Interestingly enough, he came up with an estimate of 7.9 million for the actual 1831 population—a figure remarkably close to our own.

²² Our analysis indicates that birth rates during the Famine years averaged approximately 28 per 1,000, a 25 percent reduction on their precrisis level. A preliminary analysis of several parish registers on deposit in the National Library, Dublin, provides some independent evidence on our figures. The average number of baptisms during the Famine period seems to have been just over two-thirds of the average number of the early 1840s. Even had the birth rate remained as before, the number of baptisms would have declined in line with the population. In the event, the average annual population of Ireland of 7.5 million was some 90 percent of its 1841–1845 average. On the heroic assumption that the parishes examined experienced a similar population decline, the Famine birth rate would have been similar to that in the text.

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Table A1.—Emigrants from Ireland during the period 1821–1851

Year	Emigrants to North America	Estimated emigrants to Britain		
		Basis A	Basis B	Basis C
1821	13,000	25,000	15,000	15,000
1822	13,000	25,000	15,000	15,000
1823	13,000	25,000	15,000	15,000
1824	13,000	25,000	15,000	15,000
1825	13,719	25,000	15,000	15,000
1826	18,450	25,000	15,000	15,000
1827	21,741	6,000	15,000	15,000
1828	16,685	6,000	15,000	15,000
1829	20,143	6,000	15,000	15,000
1830	38,444	55,000	15,000	45,000
1831	68,112	55,000	15,000	45,000
1832	65,397	55,000	15,000	45,000
1833	37,316	55,000	15,000	45,000
1834	49,243	55,000	15,000	45,000
1835	24,071	55,000	15,000	45,000
1836	26,500	6,000	15,000	15,000
1837	48,191	6,000	15,000	15,000
1838	11,057	6,000	15,000	15,000
1839	31,733	6,000	15,000	15,000
1840	54,713	6,000	15,000	15,000
1841	67,351	9,000	36,200	15,000
1842	92,804	9,000	36,200	15,000
1843	38,265	9,000	36,200	15,000
1844	55,294	9,000	36,200	15,000
1845	77,286	9,000	36,200	15,000
1846	105,955	135,000	36,200	100,000
1847	215,444	112,000	36,200	100,000
1848	178,159	90,000	36,200	70,000
1849	214,425	70,000	36,200	50,000
1850	209,054	50,000	36,200	40,000
1851 ^a	44,871	15,000	9,050	10,000

^a Up to March 31

Table A2.—Estimated mortality for the period 1821–1841^a

Age	Male			Female		
	l_x	$1000q_x$	e_x	l_x	$1000q_x$	e_x
0	100000	172.9	38.3	100000	135.2	38.3
1	82711	60.3	45.4	86482	64.8	43.3
2	77723	33.1	47.3	80877	37.3	45.3
3	75149	22.2	47.9	77863	25.5	46.0
4	73482	16.5	48.0	75879	18.6	46.2
5	72270	12.5	47.8	74466	13.9	46.1
10	69174	5.0	44.9	70869	6.0	43.4
15	67644	4.6	40.8	68964	5.7	39.5
20	65753	7.5	36.9	66638	8.9	35.8
25	63212	8.3	33.3	63570	10.0	32.4
30	60521	9.2	29.7	60315	11.1	29.1
35	57530	13.2	26.2	56757	15.6	25.8
40	53253	18.0	23.1	51879	20.4	23.0
45	48198	22.6	20.3	46475	23.9	20.4
50	42506	28.5	17.8	40844	27.7	18.0
55	36231	34.8	15.5	35163	33.7	15.5
60	29956	41.6	13.3	29156	41.5	13.3
65	23803	50.4	11.2	23167	50.3	11.3
70	17987	61.1	9.2	17518	60.8	9.3
75	12782	73.9	7.2	12475	73.4	7.2
80	8435	97.4	4.9	8255	96.8	4.9
85	4091	187.9	3.0	4026	188.3	3.0

^a Computed by back projection of 1841 Census figures to 1821.

Table A3.—Estimated expectation of life, Ireland, 1821–1841, and England, 1838–1854

Age	Male		Female	
	Ireland 1821–1841 ^a	England 1838–1854 ^b	Ireland 1821–1841 ^a	England 1838–1854 ^b
0	38.4	39.9	38.3	41.0
1	45.4	46.7	43.3	47.3
5	47.8	49.7	46.1	50.3
10	44.9	47.0	43.4	47.7
15	40.8	43.2	39.5	43.0
20	36.9	39.5	35.8	40.3
25	33.3	36.1	32.4	37.0
30	29.7	32.8	29.1	33.8
35	26.2	29.4	25.8	30.6
40	23.1	26.1	23.0	27.3
45	20.3	22.8	20.4	24.1
50	17.8	19.5	18.0	20.8
55	15.5	16.4	15.6	17.4
60	13.3	13.5	13.3	14.4
65	11.2	10.8	11.3	11.5
70	9.2	8.4	9.3	9.0
75	7.2	6.5	7.2	6.9
80	4.4	4.9	5.0	5.3
85	3.0	3.7	3.0	4.0

^a See text for procedures

^b From Journal of Institute of Actuaries (1892)

Table A4.—Estimated mortality during the Irish famine

Age	Male			Female		
	l_x	$1000q_x$	e_x	l_x	$1000q_x$	e_x
0	100000	328.5	18.7	100000	243.3	22.4
1	67150	114.6	26.9	75667	116.6	28.6
2	59456	62.9	29.4	66841	67.1	31.4
3	55715	42.1	30.4	62357	45.9	32.6
4	53367	31.3	30.7	59496	33.5	33.2
5	51695	30.9	30.7	57502	27.6	33.4
10	45898	16.3	29.4	51107	11.9	31.6
15	42513	15.5	26.6	49362	11.2	28.3
20	38916	21.2	23.8	46110	17.7	25.1
25	34853	22.8	21.4	41983	19.9	22.4
30	30963	24.4	18.8	37812	21.9	19.7
35	27118	32.2	16.2	33500	30.8	16.9
40	22529	41.6	14.0	27994	40.3	14.9
45	17895	50.5	12.2	22461	47.4	13.0
50	13493	62.0	10.5	17335	54.8	11.3
55	9498	74.3	9.1	12829	66.7	9.6
60	6284	87.6	7.8	8791	82.2	8.1
65	3883	104.7	6.5	5516	99.7	6.8
70	2107	125.6	5.4	3121	120.4	5.5
75	1019	150.6	4.2	1556	145.3	4.3
80	421	196.4	2.7	662	191.7	2.7
85	87	376.9	1.3	141	372.9	1.4