UNIVERSITY OF MANCHESTER

WORKING PAPERS IN ECONOMIC AND SOCIAL HISTORY

No.41

Infant Mortality in Victorian Britain: an economic and social analysis

Robert Millward and Frances Bell

INFANT MORTALITY IN VICTORIAN BRITAIN: AN ECONOMIC AND SOCIAL ANALYSIS

Robert Millward and Frances Bell

University of Manchester

(December 1999)

Working Paper n. 41

Department of History
University of Manchester
Manchester
Manchester M13 9PL
0161-2753086

I

Infant mortality in some regions of Europe may have been declining over a very long period. Levels of infant deaths of 200 to 300 per 1000 births have been recorded in France, Sweden and England in the eighteenth century and by the 1840s they were nearer to 150.[1] This trend was then halted and reversed in those areas experiencing the worst blights of rapid urbanisation so that the undisputed long term decline is commonly put at the beginning of the twentieth century - some forty years or so after the downturn in overall mortality. Similar turning points have been observed in the southern German states, Austria and Russia (Vallin 1981, Szreter and Mooney 1998).

It seems however from British evidence that if diarrhoeal deaths are excluded the halting and reversal are considerably diluted. The rise in infant diarrhoea at the very end of the century has been linked to several hot and dry summers (Huck 1994, 1997, Woods at al 1989/9) and by at least one writer to the surge in horse transport, and hence street manure and flies (Morgan 1999). The implications for explanations of non-diarrhoeal sources of death are considerable. In rural areas in this period diarrhoea accounted for less than 5 infant deaths per 1000 births (Williams and Galley 1995) and Lee (1991) and Williams and Mooney (1994) have demonstrated that they experienced little interruption in the long term decline in infant mortality. Explanations of the decline are difficult to find. The other implication is that in urban areas the pattern of infant mortality cannot simply be characterised as a cleaning up of the environment. Again, explanations are lacking.

Of course the issue is a complex one because of the multiplicity of economic and social factors involved and of the links between child mortality, target family size and fertility changes. Frameworks for thinking about these relationships are not lacking (cf. Woods and Woodward 1984, ch.I). Empirical assessments of some of the demographic dimensions are also available since the issue is central to the debate on the demographic transition (cf. Garret and Reid 1995, Reher 1999). A recent study of two Scottish towns (Kemmer 1997) affirmed the need for frameworks which embraced economic and social factors and which

[1] Thanks are due to the Leverhulme Trust for financial support.

could be empirically tested over a wide data set. This paper describes a first attempt to set out a consistent integrated framework and to test it using information on a sample of 36 towns in England and Wales in the Victorian period. The approach involves focusing on the infant's immediate environment and its inheritance from the mother : the foetus, the immune system, feeding practices and child care. This is not an exercise in demography. The Registrar General's data which are used for the mortality and fertility estimates are well known. The main contribution arises from the conceptualisation and quantification of the links between economic/social forces and the demographic trends. In addition the paper addresses the problem of 'simultaneity', that is, that the levels of infant mortality, fertility and female health are interlinked and determined simultaneously.

II

The pattern of mortality to be explained is shown in Table 1 and illustrated in Figure 1 which includes data for the 1860s not used in the later statistical work. They relate to a sample of 36 towns in England and Wales, the groupings of which are defined in the footnote to Table 1. The 'town' basis of the data arises from the need to set the demographic trends against economic data which are not usually available for individuals (but see Reid 1999). Important geographical, economic and social variations are captured by the sample embracing rural townships like Marlborough and Thetford, as well as towns like Leeds and Nottingham with classic nineteenth century housing and factory blight, seaside towns like Blackpool full of single females in domestic and hotel service, mining and heavy industry towns with strong patriarchal cultures and large middle class pockets in suburban Kingston-on Thames and Tottenham.

TABLE 1
INFANT MORTALITY BY DECADE
(Sample of 36 towns in England and Wales 1875-1905)

YEAR	Text. -iles	Ports	Min- ing, glass etc.	Mix- -ed indus- -trial	Sea -side towns	Mid- ddle class towns	Farm	Rest	Total
Infant Deaths from Diarrhoea per 1000 births									
1875	32.2	19.3	18.3	27.6	21.9	18.3	10.4	21.4	20.3
1885	26.4	14.1	15.0	26.0	14.5	15.0	6.7	16.0	15.8
1895	30.8	20.7	19.4	32.6	20.1	13.2	8.2	18.8	19.6
. 1905	22.4	18.7	18.1	28.0	12.9	13.7	4.8	14.6	15.9
Infant Deaths from Causes other than Diarrhoea, per 1000 births									
1875	160	146	141	160	117	117	111	132	135
1885	153	138	146	152	119	114	102	125	130
1895	156	154	158	158	123	121	102	133	126
. 1905	130	127	133	133	99	86	87	109	112
Total Infant deaths per 1000 births									
1875	192	165	159	188	139	135	121	153	155
1885	179	162	161	178	133	129	109	141	146
1895	187	175	177	191	143	134	110	152	156
1905	152	146	151	161	112	100	92	124	128

Key to Towns : Textiles (Bradford, Leeds, Preston) ; Ports (Bristol. Liverpool, Plymouth, Sunderland, Swansea, Southampton) ; Mining , glass and potteries (Wrexham, St.Helens, Stoke) ; Inland mixed industrial towns (Doncaster, Leicester , Manchester, Nottingham) ; Suburbia/middle class towns (Kingston -on- Thames, Oxford, Tottenham) ; Seaside towns (Blackpool, Hastings, Ramsgate) ; Farming townships (Gt. Torrington, Lincoln, Louth, Marlborough, Shaftesbury, Thetford) ; Rest (Carlisle, Carmarthern, Luton, Northampton, Norwich, Richmond (Yorks.), Wolverhampton, York).

Notes and Sources

The main sources are the annual and decennial reports of the Registrar General 1860-1920. Decadal data on births and deaths for each town were assembled, a decade average was estimated and the rates of deaths per 1000 etc. in each town were calculated and then centred on the middle of the decade (e.g.1875). The specific data were :

Births : Decade totals of births were cumulated from the RG annual reports and then divided by 10.

Infant deaths: The cumulative totals in the RG decennial reports were divided by 10. The cause of death data on which the diarrhoea figures are based are:

1861-70 Diarrhoea / dysentery, cholera ;1871-80 Enteric fever, diarrhoea / dysentery, cholera ; 1881-90 Enteric fever, diarrhoea / dysentery, cholera ;1891-1900 Enteric fever, diarrhoea / dysentery, cholera ; 1900-10; Enteric fever, diarrhoea / dysentery.

FIGURE 1

TABLE 2
FOOD, HOUSING AND , POPULATION 1874-1906
(Sample of 36 towns in England and Wales)

(Annual averages)

	Text. -iles	Ports	Min- ing, glass etc.	Mix- -ed indus- -trial	Sea -side towns	Mid- ddle class towns	Farm	Rest	Total
House Occupancy									
1874/71	4.91	6.86	5.46	4.85	5.89	5.52	5.52	5.09	5.55
1903/6	4.44	4.83	5.28	4.56	4.54	5.09	4.41	4.71	4.70
Food Bundles									
1874/7	32.1	28.6	31.5	30.6	28.8	30.0	27.1	28.5	29.2
1903/6	48.5	46.2	47.6	46.3	43.6	45.4	40.9	43.1	44.1
Population Density									
1874/7	23.2	44.3	13.6	45.0	10.5	12.6	7.5	15.3	22.0
1903/6	25.0	41.2	15.0	29.0	20.5	26.2	8.1	20.9	23.3

Notes and Sources

The years 1874/7 and 1903/6 were chosen to avoid certain years when some of the other data, used later on, are patchy. The entries for house occupancy and population density are derived from data on population, acreage and the number of houses, interpolated from the decennial Censuses of the Population of England and Wales and relate to borough boundaries. Some of the boundaries change in the period and affect the density figures. The entry for food bundles constitutes the number of baskets of a given bundle of food which could be bought from local builders' wages at local food prices. Each bundle comprises 4lbs of bread, 7lbs of potatoes and 3 eggs. Its cost was derived from the Board of Trade Report (1908) on the cost of living in different towns in 1905, extrapolated backwards with the Rousseau price index in Mitchell, 1988 pp.723-4. Data from the same report on builders weekly wages were extrapolated back by data in Mitchell (1988, pp.151-2,728) on the national movement in average money wages.

The data are expressed as decadal averages to highlight the longer term trends which are the focus of the paper. Nevertheless the rise of infant mortality in the 1890s is clear and Table 1 implies that though the effect is very pronounced for diarrhoeal deaths (the middle class towns excepted) there is also a rise in infant deaths from non-diarrhoeal sources (farming townships excepted) suggesting that whether the carriers were flies or water, the Registrar-General's diarrhoea category did not capture all the effects.

So far as levels of mortality are concerned there are two significant features. One is the large difference between the inland industrial towns and the suburban and farming towns. For diarrhoea deaths the remaining groups - ports, mining and seaside towns - lie fairly close together, roughly half way between the two extremes. The environmental basis of these placings relate to population density and ease of access to waste disposal which count as good proxies for exposure to disease affecting all age groups. The other striking feature is that comparisons of the 1860s with the early 1900s suggest a long term decline in infant mortality in all areas. The decline in the textile groups is substantial, absolutely and proportionately, whilst for the mining towns the change is modest and absent for diarrhoeal deaths. These features require an explanation. The farming townships have the lowest infant mortality but even they experience a large decline. Hence cleaning up the urban environment does not capture the whole of the improvement in infant health. In our earlier work we found that expenditure on the sanitary infrastructure showed a significant burst only at the very end of the century and cannot have been a force in the decline of overall mortality from the 1870s (Bell and Millward 1998). Neither was there any relief from population densities which, as Table 2 shows, continued to rise, with very large increases in the newest settlements - the seaside towns and suburbia. Improvements in the size and quality of the housing stock seem to have been important for overall mortality. The number of houses rose faster than the population and, as Table 2 shows, average house occupancy fell in all areas. In addition an attempt was made in our earlier work to capture some of the dimensions of resistance to disease by calculating for each town a food availability variable, specifically the food consumption affordable in each town in each year from contemporary wages and food prices. Increase in food availability so defined proved to have a powerful influence on the decline in overall mortality in the 1870-1914 period (Millward and Bell 1998). This is a

period when real incomes rose on average by about 50% and this is reflected in the increases in food availability recorded in Table 2.

III

Whether solid food, population densities and housing were directly important for infant mortality is however doubtful since the health of an infant was heavily dependant on what it inherited from the mother, on the amount of breast feeding and of child care. The mortality of infants differs from that of other age groups in its overwhelming dependence on the condition of the foetus, on what the mother passes on in the immune system and , as Wray (1978) has convincingly demonstrated, on the quantity and quality of breast feeding. The association of high infant mortality with poor environments, even when controlled for the influence of 'class', may not be revealing the whole story. Williams' excellent account of infant mortality in 1860s Sheffield (1992) shows how environmental and socio-economic differences had independent influences, even in the unhealthy low lying areas bordering the rivers Don and Sheaf. An earlier analysis by Watterson (1986) of the same town using 1911 census returns concluded that socio-economic status was less important than environment in accounting for the decline of infant mortality over the 15 years before Census. The role of the environment in this setting may well exert its most powerful influence through the prior history of the mother up to pregnancy and thereby to what she passes on to the child (cf. Cronje 1982, Wray 1978). Analyses which focus on the observed association between infant mortality and the contemporaneous environment may be obscuring or at best acting as a proxy for the real mechanisms involved.

An analytical framework is now developed which allows the links between infant mortality, socio-economic factors and the environment to be traced and quantified. Neo-natal mortality is considered first , followed by an analysis of post neo-natal mortality and its links with feeding practices, fertility and female employment. Clearly there are some variables like breast feeding and the condition of the foetus for which data are absent or patchy and proxies will be developed as their roles are identified. In the final section of the paper the whole framework is tested against the pattern of infant mortality across the sample of towns for each of the years 1870-19105.

The pattern of neo-natal mortality was clearly different from mortality in the later months of an infant's first year. Neo-natal mortality showed no signs of long term decline up to the 1930s, averaging about 40 deaths per 1000 births in the 50 years up to World war I. This stability is also found in maternal deaths at childbirth and though the death rate was much lower (40 per 10,000 births) the two were closely associated across the different regions of Britain (Loudon 1988, Newsholme 1910).

Spatial variations did not seem to follow the urban/rural pattern found for other r age groups. Here is Newsholme, the Medical Officer of Health to the Local Government Board in 1913 : 'At birth... the urban infant is about as healthy as the rural, and during the first month of life, during which over one third of infant mortality occurs, the urban excess is usually about 8% (1912/13, pp.3,4). More recent observers have also found small differences in neo-natal mortality between urban and rural (Woods et al 1988/9, Huck 1994, Williams and Galley 1995). Spatial differences seem to be linked to the size of town suggesting, as with maternal mortality (cf. Loudon 1988) that obstetric help was deficient in remote rural areas, mid Wales being an oft quoted example.. The data on neo-natal mortality are patchy. The main diagnoses were low birth weight, premature births and congenital defects. Newsholme, conscious of the uncertainties in the way death was recorded, argued that the causes of such deaths were similar to those associated with deaths from atrophy, debility and marasmus, 40% of which occurred in the first months of life. He felt it safer to lump all of these together and the resultant figures showed a stability over time similar to maternal mortality. Moreover the rates were higher in Durham, Northumberland and Wales and lower in the home countries, south west and south east. For our sample of towns there are no readily available time series on neo-natal mortality. Annual averages for the period 1907-10 for 28 of the towns have been extracted from Newsholme's report and recorded in Table 3. There are some signs that towns like Liverpool and Doncaster ranked lower in neo-natal rates (first column) than in the overall infant mortality rates (last column) suggesting that obstetric help may have been significant in these towns. Similarly Luton and Northampton had rather high neo-natal mortality rates relative to their overall rates. The same characteristics can be found in Table 4 which is derived from Newsholme's disease breakdowns. Deaths from childbirth, atrophy etc. again exhibit rather lower

TABLE 3

INFANT MORTALITY BY MONTH IN TOWNS IN ENGLAND AND WALES

(Deaths per 1000 births in administrative districts : annual average 1907-10)

	Under 1 month	Under 1 week	2-5 months	6-12 months	Under 1 year
Stoke	45.3	26.8	68.5	48.1	162.9
Preston	43.9	27.5	61.7	46.4	152.0
Nottingham	46.7	28.3	60.9	39.8	147.4
Liverpool	40.4	23.2	55.9	45.2	141.5
Manchester	44.8	25.1	54.8	41.5	141.1
Swansea	43.0	25.1	57.4	40.2	140.6
St. Helens	48.3	30.3	44.8	43.4	136.5
Doncaster	31.0	19.7	58.0	47.2	136.2
Sunderland	47.5	29.5	47.9	39.7	135.1
Leeds	43.6	26.5	48.6	38.4	130.6
Bradford	48.3	30.7	44.6	34.9	127.8
Leicester	41.4	23.7	51.2	35.0	127.6
Wolverh'pton	45.0	24.6	47.8	34.2	127.0
Carlisle 44.9	27.3	48.0	33.6	126.5	
Plymouth	39.6	22.4	50.4	30.9	120.9
Blackpool	39.6	25.4	46.9	31.2	117.7
Norwich	39.6	24.9	46.7	30.4	116.7
Luton	45.8	30.6	44.4	22.9	113.1
Northampton	42.3	24.9	42.0	24.8	109.1
York	38.9	26.1	39.1	27.7	105.7
Ramsgate	32.3	16.6	48.5	24.5	105.3
Bristol	39.4	24.3	39.2	26.2	104.8
Southampton	38.9	25.8	38.1	24.5	101.5
Lincoln 34.9	20.6	38.4	23.9	97.2	
Tottenham	34.4	20.3	25.1	24.1	92.6
Oxford	35.1	22.9	32.6	18.9	86.6
Kingston	36.5	24.7	30.5	21.4	88.4

Hastings	30.9	19.8	31.6	18.8	81.3

Source : Appendix II, Table I Newsholme's 2nd report 1912-13.

TABLE 4

CAUSES OF INFANT DEATHS IN TOWNS IN ENGLAND AND WALES

(Deaths per 1000 births in administrative districts : annual average 1907-10)

	Diar-rhoea A	Child birth B	Atro-phy C	TB, bronch. D	Mea-sles E	Conv-ulsions F	Other G		Total
Stoke	23.6	24.6	30.7	35.0	8.4	20.7	18.9		162.9
Preston	21.7	32.4	24.4	33.6	9.6	11.4	18.9		152.0
Nottingham	22.8	35.8	13.7	32.8	8.4	8.0	25.9		147.4
Liverpool	21.1	24.4	21.8	29.1	9.2	13.0	22.9		141.5
Manchester	20.4	27.0	23.2	33.0	9.8	5.7	21.2		141.1
Swansea	16.5	19.0	24.0	28.7	8.8	26.8	16.8		140.6
St. Helens	13.6	39.7	11.8	28.8	9.0	13.2	20.4		136.5
Doncaster	23.4	24.8	20.0	24.9	8.3	15.8	19.0		136.2
Sunderland	12.0	25.7	31.4	32.4	8.3	8.8	15.4		135.1
Leeds	18.8	28.2	15.7	29.5	6.4	9.2	22.8		130.6
Bradford	14.3	30.9	21.4	23.9	8.1	10.4	18.8		127.8
Leicester	20.0	24.2	22.3	23.5	7.2	13.2	17.2		127.6
Wolverh’pton	18.8	22.6	20.7	31.7	8.0	4.1	21.1		127.0
Carlisle 12.4	27.2	17.7	31.3	8.9	5.3	23.7		126.5	
Plymouth	19.3	21.2	18.3	25.7	7.2	8.8	20.4		120.9
Blackpool	15.0	26.6	15.2	25.4	6.0	8.0	20.5		117.7
Norwich	13.8	24.7	20.1	25.3	5.7	12.7	13.4		116.7
Luton	10.4	34.0	14.8	19.1	6.3	11.9	16.6		113.1
Northampton	10.2	28.8	20.4	21.6	6.0	6.5	15.5		109.1
York	16.9	24.8	20.8	17.5	4.1	10.8	10.8		105.7
Ramsgate	22.4	22.8	12.9	22.0	7.4	9.5	8.3		105.3
Bristol	13.7	21.7	10.5	20.2	6.1	9.9	22.7		104.8
Southampton	14.5	30.8	13.1	20.8	5.0	4.8	12.5		101.5
Lincoln 13.0	20.2	19.1	16.6	5.6	8.8	13.9		97.2	

Tottenham	6.6	20.8	12.5	22.9	4.9	5.4	19.5	92.6
Oxford	7.6	24.3	17.3	19.4	5.1	2.3	10.6	86.6
Kingston	10.4	29.1	4.9	19.7	7.4	4.7	12.4	88.4
Hastings	3.4	23.2	14.5	14.2	9.6	4.6	11.8	81.3

Key
A=Diarrhoeal diseases.
B=Premature births, congenital defects and injury at birth.
C=Atrophy, debility and marasmus.
D=Tuberculous diseases, bronchitis and pneumonia.
E=Measles and whooping cough.
F=Convulsions.
G=Other, including want of breast milk.

Source : Appendix II, Table I Newsholme's 2nd report 1912-13.

levels in Liverpool and higher rates in Luton and Northampton that the overall infant mortality rates would suggest.

However the main message from this data is that other factors besides obstetric help are of equal or greater importance. One is the domestic environment - the size of the house, its cleanliness, the quality of water and the extent of sewer links. This also affects post neo-natal mortality and will be considered later. Another factor and a key one is the condition of the foetus. Because most women breast fed for at least the first few weeks, it is unlikely that the immune system inherited from the mother played much of A part in infant deaths in these weeks. Rather it is the mothers' nutritional state which would determine immaturity and congenital defects. That factor might be proxied by some measure of mother's health to be considered later. In the meantime there is the vexed question of the effects of female paid employment on the foetus, on which the literature still seems divided. Graham (1994) has argued that in this period there were strong links between female employment, prematurity and general perinatal (first week) mortality, quoting examples from Dundee jute mills and Northampton shoe factories. Weavers, charwomen and bar staff all seem to have been associated with high neo-natal mortality rates but so also did typists and the stretching involved in housework could be as dangerous as stretching over a loom. As Collet argued a long time ago, much depends on the nature of the work. The Medical Officer of Health for Kensington was at pains, in his 1911 report, to argue that the arduous nature of laundry work in the Notting Dale Special Area did not have an 'adverse' effect on the child in

pregnancy and in trying to explain the high level of infant mortality put more weight on post neo-natal feeding practices (Tanner and Mooney 1997. p.13). It will nonetheless be useful to test for the influence of female employment in this context and the scope for doing this is explored later in the paper.

IV

As one moves away from deaths in the first month, the classic excess of urban over rural mortality emerges which, according to the Registrar General in 1891, peaked at 273% in the sixth month (Williams and Galley 1995). Breast milk is crucial in months 2 to 6 in providing a shield against the domestic and community environment. Months 7 to 12 see environmental factors continuing to play a role but now one must expect the quality and quantity of solid food to be important. The importance of sanitary improvements has been stressed from Chadwick, through Newsholme, onwards. For the Victorian period Buchanan (1985) has emphasised the importance of sanitary developments in the mining villages of S.Wales and Lancashire, contrasting with the Durham mining settlements where the scattered rural communities like Houghton and Hetton suffered less from their poor sanitation than other areas (p.171). Both Kintner (1988) and Brown (1997) have shown statistically that the presence of sewer links was an important ingredient of infant mortality differences across towns in Germany at the turn of the century. Buchanan has actually laid the blame for the persistence of infantile diarrhoea into the 1900s to the failure to replace conservancy systems with proper sewerage (p.162), though he does not produce any

general evidence. What still needs to be explained is the contribution of sanitation and indeed other environmental improvements like housing to the decline in infant mortality

The same could be said about conditions in the domestic environment. In part this relates to the presence or absence of WCs and sewer links in good quality houses. These conditions as well as the conditions in the community environment will be quantified by data for the sample towns on population density and the size of the housing stock as well as municipal expenditure on water and sewer systems, street cleaning, scavenging and maintenance. But a crucial factor in that environment was family size. First it affected the time available for the mother to spend on the care of each child (Woods et al 1988/9, Reves 1985). Secondly claims on household food were higher the larger was family size. This may be especially important in months 6-12 as the child is weaned on to solid foods and may explain the pattern for these months, sometimes observed in 3rd World countries, of breast feeding being clearly inadequate

FIGURE 2

as the sole source of nutrition (Fildes, 1991, p.218). The third effect of family size links to the role of the domestic environment. Exposure to disease is affected by the proximity of contaminated objects, insects and humans. Reves has argued that observed links between the size of the housing stock, population and infant mortality may be obscuring the more important issue : the number of susceptibles. Whatever the size of the house, large families mean a large number of nearby susceptibles and hence raises exposure to disease. Reves' basic thesis is that the decline of fertility from the 1870s in England and Wales was thereby a key ingredient in the decline of mortality. He did not control for other factors but we can explore this mechanism by the data we have on population, housing numbers and fertility levels in towns with different water and sewer capacities and food availabilities. For the moment it is worth noting that the potential role of fertility in the pattern of infant mortality in the sample towns is shown by the decadal averages in Figure 2, the source data for which are described later (Table 5). It is clear that, notwithstanding one or two wobbles, there is a

downward trend in all sectors. The textile towns of Preston, Leeds and Bradford still have relatively high levels in the 1860s but their fall is proportionately greater than every other sector except perhaps the seaside towns which were affected by the influx of single women seeking employment in hotels and services. Here are found the lowest levels of fertility with suburbia next and the cultural influence of the latter's middle class may be compared with the male dominated culture of the mining towns at the other extreme.

To summarise the argument so far, post neo-natal infant mortality is expected to be linked in part to the condition of the domestic and community environment especially in the context of the food and water borne diseases. Fertility levels and/or family size affect the number of susceptibles, the volume of solid food available per family member and the time which mothers could spend on child care. The other main factor to which we now turn is the quantity and quality of milk which in months 2 to 6 crucially supplement the resistance to disease which is initially provided by the immune system. Whilst the virtues and cheapness of breast feeding have been well documented (Dyehouse 1978, Wray 1978, Buchanan 1985) the evidence of its incidence is patchy. Fildes' surveys (1991, 1992) provide a picture for certain towns in the early 1900s and there seems to be agreement with Newsholme's earlier observation that in the period up to the First World War, 80% of infants were breast fed for several months, a high figure by European standards and often invoked as the cause of the below average level of infant mortality in Britain. There are also clear indications for the period 1890-1914 for towns like Rhondda, Poplar, Stoke, Finsbury and Kensington that the proportion of breast fed infants who survived was higher than for infants not breast fed, that the infant diarhhoeal mortality rate was some 5 times higher for infants not exclusively breast fed and that the death rate from non-diarrhoeal sources was about 4 times higher (derived from Fildes 1992, Holdsworth 1997, Tanner and Mooney 1997). There are however no time series data of any significant length to gauge whether breast feeding fell during the nineteenth century. The most that can be said is that industrialisation was bringing artificial foods on to the market ; these were taken up by the middle classes, a practice copied by others, but were especially dangerous if not stored properly. Atkins(1992) has suggested that the sweetened milk which emerged in the 1880s and fresh milk transported over long distances from unregulated rural cowsheds were particularly unsafe. These developments may be one of the factors in for the halting and reversal of the decline in infant

mortality in the 1890s, especially bearing in mind Huck's demonstration (1997) that it would only have taken a small change in the incidence of breast feeding to trigger a large change in infant mortality.

At this stage of the argument, it clear that there are three important variables for which direct measures are absent : breast feeding, the immune system inherited by the child, the condition of the foetus. There are good reasons for thinking however that a prime determinant of all these was the health of the pregnant female. Differences across towns and over time in mothers' health may act as a proxy for the three missing pieces of data and thereby provide the key to constructing a testable framework for infant mortality.

V

That the health of the pregnant female is a key influence on the condition of the foetus, the immune system and of the quality of breast feeding is widely acknowledged (Wray 1978, Cronje 1984, Loudon 1988, Harrison 1988). If a measure of mothers' health could be devised, it would be expected to play a significant part, along with measures of the environment, family size, family resources, female employment and obstetric help in explaining infant mortality patterns. Female mortality rates are not sufficiently specific to the child bearing age to be a good measure whilst maternal mortality (from child birth, that is) seems likely to be reflecting mainly obstetric help. The mortality rate of females aged, say 15-44, would be better but it is well known that differences over time and across towns in such rates would reflect the quality of the contemporary domestic and community environment which is not what is desired here. The measure should reflect the mothers' resistance to disease, her nutritional state, rather than her exposure to the contemporary environment. The death rate of females aged 15-44 from tuberculosis seems the best proxy available since it is accepted as reflecting primarily the mothers' current resistance to disease (which will reflect her whole past health history) and less sensitive to the current environment (Cronje 1982, Collis 1940). High TB rates may of course lower a woman's fertility and hence have feedback effects on infant mortality through changes in family size but such feedback effects are precisely what it is intended to capture in the framework which

follows. It is known that TB rates were higher for women than men in the early decades of the nineteenth century, especially in rural areas, largely due, it is assumed, to the ruling family food hierarchies. Thereafter the death rate fell faster for women than men but generally did not overtake men until the early 1900s (Collis 1940, Woods 1984). Figure 3 shows the main trends in mothers' health so defined. The raw data come from the Registrar-General's reports which contain some gaps which are overcome by methods described in the footnotes to Table 5.

The differences across sectors do not accord with environmental differences (contrast infant mortality Figure 1) or cultural differences (contrast Figure 2 on fertility). This is to be expected since TB reflects resistance to disease and nutritional status. What is particularly relevant is that all sectors show a decline in both TB deaths and non-TB deaths of women in the 15-44 age group. The fall in the TB rate is greatest for the textile sector and suburbia and smallest for the ports and seaside towns. That pattern will be explained as part of the full model analysed later.

FIGURE 3

TABLE 5

MORTALITY AND FERTILITY OF FEMALES AGED 15-44

(Sample of 36 towns in England and Wales 1875-1905)

Text. -iles	Ports	Min- ing, glass	Mix- -ed indus-	Sea -side towns	Mid- ddle class	Farm	Rest	Total

etc. -trial towns

Births per 1000 women aged 15-44 years

YEAR									
1875	153	148	197	168	117	124	148	142	149
1885	127	138	170	143	100	120	137	135	135
1895	113	129	165	130	86	102	116	121	121
1905	91	119	146	117	71	93	100	103	106

Female TB deaths per 1000 women aged 15-44 years

1875	3.96	3.58	3.34	3.34	3.02	2.50	3.48	3.44	3.38
1885	3.11	3.19	2.55	2.74	2.48	1.87	2.71	3.14	2.82
1895	2.32	2.70	2.10	1.98	1.96	1.27	1.95	2.33	2.15
1905	1.71	2.03	1.56	1.54	1.61	1.07	1.72	1.82	1.70

Female NON -TB deaths per 1000 women aged 15-44 years

1875	97.98	96.41	93.02	89.15	73.40	57.38	80.61	79.91	83.98
1885	81.27	85.21	83.89	75.79	64.89	46.11	68.81	67.69	72.15
1895	71.15	79.05	77.82	73.10	53.85	36.08	53.18	61.82	63.81
1905	55.22	61.61	58.71	55.58	45.53	31.35	41.47	50.70	50.52

Female total deaths per 1000 women aged 15-44 years

1875	101.94	99.99	96.36	92.49	76.42	59.88	84.09	83.35	87.36
1885	84.38	88.41	86.44	78.53	67.40	47.99	71.52	70.83	74.97
1895	73.47	81.75	79.92	75.07	55.81	37.35	55.14	64.15	65.96
1905	56.93	63.65	60.26	57.12	47.14	32.42	43.19	52.52	52.22

Notes and Sources

The sources are the annual and decennial reports of the Registrar General 1860-1920. Data on births for each town from the annual reports were cumulated and divided by 10 to yield decade averages. From the decennial reports the data on average female population aged

15-44 were assembled as were the figures on cumulative deaths of females 15-44 which were then divided by 10. The rates of deaths and births per 1000 etc. in each town were calculated and then centred on the middle of the decade (e.g.1885). For the 1870s no female /male population split by age group is available so the male/female split for the 1870s is interpolated from the 1860s and 1880s splits. For details of the calculation for TB deaths see below. The entries for the non-TB death rates were obtained by subtracting the TB rates from the overall female death rate.

Deaths of females aged 15-44 from tuberculosis : The cumulative totals in the RG decennial reports were divided by 10. Some interpolation was needed for some decades. An age specific male/female breakdown of TB deaths is available in the RG decennial reports for the 1850s, 1860s and 1900s but not for the intervening decades. For all decades the RG reports do contain data on TB deaths of females of all ages as well as male and female combined figures of TB deaths of 15-44 year olds. An estimate for each town for each decade was calculated as the average of two separate estimates as follows.
We first made the assumption that the shares of female TB deaths (in a given town) accounted for by the 15-44 age group fell smoothly as between the known levels(for that town) of the 1860s and 1900s. The shares of the intervening decades were then interpolated and applied to the known figures (for each decade for that town) of female TB deaths of all ages . A second estimate was obtained by assuming that the share of females in all TB deaths (in a given town) of 15-44 year olds declined smoothly from the known level of the 1860s to the known level of the 1900s. Shares for the intervening decades were then interpolated and applied to the known figures (for each decade for that town) of all TB deaths in the 15-44 age group. The entries in the table are based on a simple arithmetic average of these two estimates for each town for each decade.
The disease deaths which have been taken from the RG's decennial reports to derive the above are :
1870s : Scrofula, Tabes Mesenterica, Phthisis.
1880s : Tabes Mesenterica, Phthisis, Other TB & scrofula diseases.
1890s : Tabes Mesenterica, Phthisis, Other TB & scrofula diseases.
1900s : Phthisis, Tuberculosis meningitis, Tuberculous Peritonitis, Tabes Mesenterica, Other Tuberculous diseases.

TABLE 6
FEMALE ECONOMIC ACTIVITY BY SECTOR IN 16 TOWNS IN 1891
(Percentage of total females)

	Child-ren 0-9- & stud--ents 15+	Unocc--upied	Dom--estic, baths etc	Dress etc. lodging	Text--iles	Other paid emplo-	Total --ment	Absolute total of females
Preston	22.6	31.7	6.5	2.9	31.9	4.1	100.0	58286
Leicester	23.4	35.0	7.5	21.5	1.5	5.2	100.0	92183
Nottingham	22.6	42.1	8.0	8.0	13.2	6.3	100.0	115147
Bradford	20.9	40.2	6.7	3.2	24.5	4.3	100.0	115916
Hanley (part Stoke)	25.7	43.9	10.5	3.1	0*	17.2	100.0	27609
Northampton	24.2	45.0	9.3	16.0	0*	5.5	100.0	31392
Manchester	23.3	44.0	8.6	7.5	7.2	8.6	100.0	261489
Leeds	23.7	47.3	7.2	9.4	6.2	6.2	100.0	190478
Norwich	22.6	44.8	10.6	10.3	2.5	9.1	100.0	54347
Bristol	22.2	46.3	13.8	8.5	1.2	8.2	100.0	120290
Wolverhampton	24.9	52.5	9.5	3.7	0*	12.1	100.0	41645
Plymouth	20.8	52.6	13.0	6.3	0*	8.4	100.0	44898
Southampton	23.0	54.6	12.4	4.6	0*	5.4	100.0	34399
Swansea	25.8	51.8	10.5	4.7	0*	3.7	100.0	45411
Sunderland	26.3	57.9	8.5	3.1	0*	4.5	100.0	66830
Liverpool	24.0	51.2	13.2	4.9	0.2	5.0	100.0	265554
St.Helens	29.4	54.9	7.8	2.7	0*	5.5	100.0	34085

* Negligible and included in ‘other’.

Source : Census of Population of England and Wales 1891.

The final measurable variable with a potentially direct influence on post neo-natal mortality is female employment. It is an old story, strongly challenged, that female paid employment affected the amount of breast feeding and hence infant mortality. The main danger was the use of artificial foods - their quality and the location in which they were used (Graham 1994). Garrett and Reid (1994, 1995) have stressed that the association of female paid employment with infant mortality is really a link to employed females without supporting care. The implication is that family resources (which we can proxy by real income levels or food availability) and family size must be quantified and included if female employment is to be treated as a factor in infant mortality. Holdsworth's work (1997) on the Potteries suggests that female employment did have a separate effect on infant mortality independent of breast feeding - probably through the condition of the foetus in neo-natal mortality - as well as through child care.

It seem that whilst the propensity of females to seek paid employment may affect the pattern of infant mortality across towns (as well as affecting mother's health and fertility, as we shall see), it is unlikely to play much of a direct role in accounting for trends over time since female participation rates seem to have been fairly static over the later Victorian period. Humphries ' work (1995) on the Censuses of Population suggest an overall participation rate for females aged 20-64 of about 33% which hardly changed in the 40 years or so before the First World War. The rates for females aged 10 plus were very similar and also stable. Significant differences existed geographically. For England and Wales as a whole about three quarters of all females were recorded in the late nineteenth century censuses as children less than 10 years old or students 15 plus or unoccupied. The rest, that is 25 %, were in paid employment. Towns like Northampton and Manchester averaged about 40% in paid employment whilst there were heavy industry towns like St. Helens at 20%. What is of relevance for the sample of towns in this study is that whilst females can be found in paid employment in lodging houses, wash houses and domestic service in all towns it is textiles and dress making which, unsurprisingly, create the big differences as Table 6 shows for one census year 1891. Those towns in the bottom half of the table with virtually no female textile employment have generally the lowest participation rates, Hanley (potteries) and Northampton (shoes) being the main exceptions (cf Szreter 1996). Preston (cotton) and Leicester (dress making) stick out as having by far the lowest

proportion of all females not in paid employment (54-58%). There does seem to be a break then with the clutch of other towns like Nottingham and Leeds with figures generally in the 40-50% range. It will be possible to test how far these groupings contribute to differences in infant mortality rates.

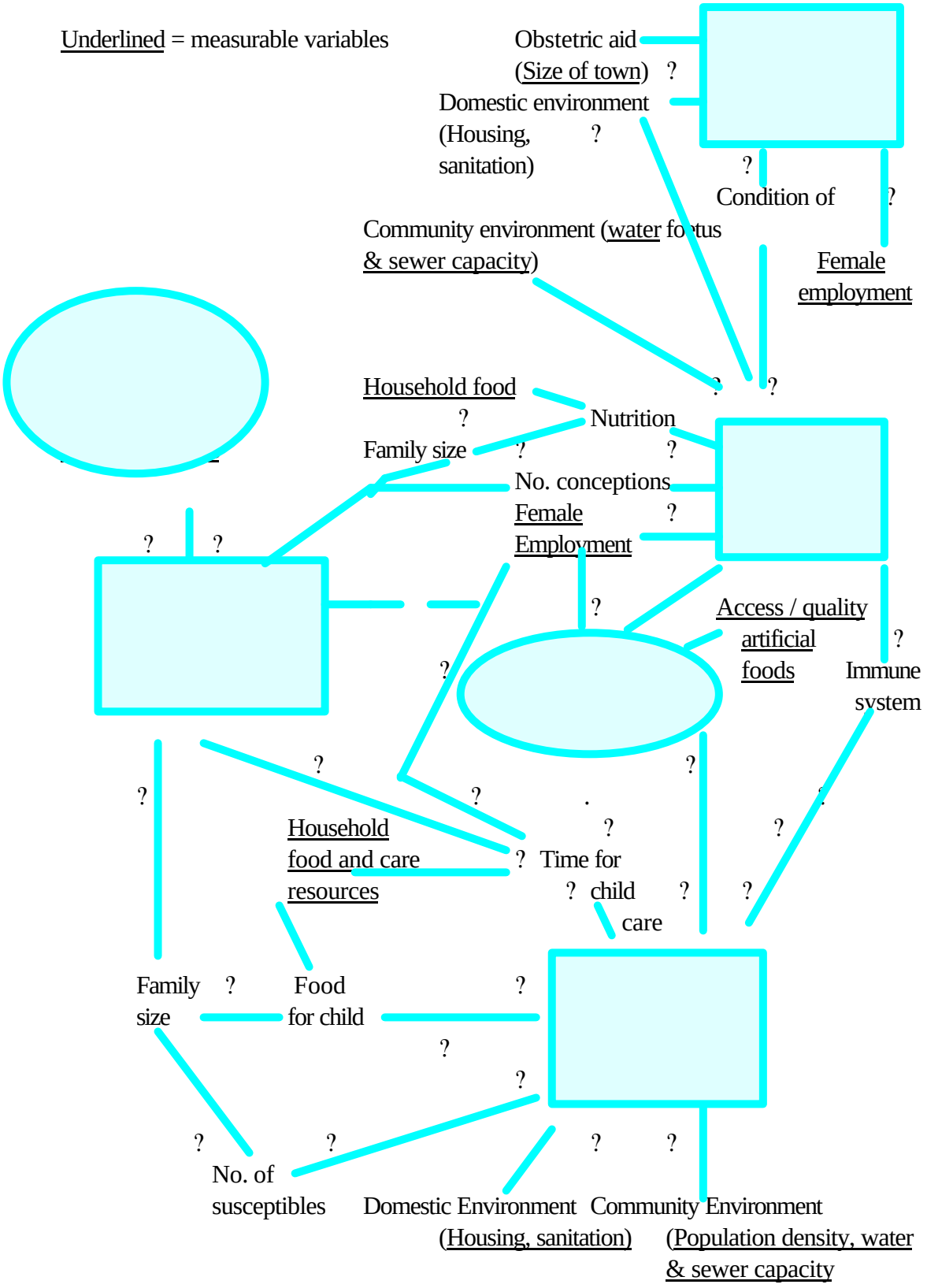
VI

Fertility and mothers' health emerge as potentially important determinants of infant mortality. Yet it is to be expected that mothers' health will affect and be affected by fertility levels whilst fertility may be affected by the survival rates of children. It is time to piece together the various elements into a consistent framework and first we need to make explicit what are likely to be the main determinants of mothers' health. Food availability and environmental conditions (as reflected in housing and population densities) have been shown earlier (Millward and Bell 1998) to affect all age groups in this period. By implication they would also play a role in mothers' health but there are several ways in which the impact might be expected to be different and ther are several other factors unique to mothers.

Thus the 'urban penalty' is partly associated with factory work and will therefore show up more for men than women in aggregate mortality figures : hence the impact of community environments might be expected to be less. On the other hand the TB death rate is our key measure of mothers' health and this will reflect resistance to disease more than exposure so that food availability would be expected to have a stronger impact than it would on non-TB sources of death. Thirdly fertility levels have some specific effects. Seccombe (1990) and Reves (1985) have both stressed the intra-uterine deficiencies from maternal depletion. In addition by affecting family size, fertility levels influence the amount of food available per family member. Finally female employment conditions can affect the health of pregnant females over and above the effects on the foetus mentioned earlier. Lead poisoning, sweat shops, polluted atmospheres : the list of nineteenth century factory conditions which impaired mothers' health is well known (Harrison 1995, Holdsworth 1997, Tanner and Mooney 1997).

FIGURE 4

INFANT MORTALITY : A COMPUTABLE FRAMEWORK



Overall infant mortality is therefore a function of the following measurable variables : household food and care resources, fertility, mothers' health, obstetric aid (reflected in size of town) and the environment (measured by water and sewer capacity, housing, population density).

The main features of the framework which emerge and for which quantifiable variables can be identified are shown in Figure 4. For the moment fertility levels may be thought of as exogenous. Infant mortality is portrayed as being influenced by general environmental conditions but more pointedly by the quality of the immune system and foetus, the quality and quantity of breast feeding, the amount of solid foods available, the time available for child care, the number of susceptibles in the house and the quality of obstetric help. Because several of these cannot be measured directly the model in Figure 4 shows infant mortality as being determined by the following measurable variables : food availability, fertility levels, mothers' health, female employment, size of towns (as proxy for obstetric help) as well as the quantified environmental variables like population density, the housing stock and the sanitary infrastructure. In its turn mothers' health is portrayed as a function of the following variables : food availability, fertility levels and female employment as well again as the environmental conditions. It is strictly illegitimate to treat fertility as exogenous since it is likely to be affected by, amongst other things, female employment, child mortality and mothers' health. Although the explanation of fertility is not the main purpose of the paper, the 'simultaneity' problem requires that it be incorporated into our framework as an endogenous variable and this is attempted in the appendix.

VII

This set of propositions is tested by running three regressions ; one with infant mortality as the dependant variable, one for mothers' health and one for fertility. The focus here is on the first two with the fertility model left to the appendix. The basic data relate to the 36 towns over each of the 36 years 1870-1905. Sources have already been described. There are of course many factors which are potentially relevant but which we cannot quantify : educational influences ; the role of religion; the culture of mining areas. The use of dummies for different sector groups (suburbia, mining etc) will help to identify the significance of some of these influences. In a similar vein a dummy for the 1890s is used to see how far the experiences of that decade (hot dry summers, surge of

TABLE 7
INFANT MORTALITY IN 36 TOWNS IN ENGLAND AND WALES 1870-1905

	REGRESSION ANALYSIS			CHANGES 1874/7-1903/6		
	Death from Diarrhoea	Death from Other Causes	Total Deaths	% Change	% Contribution to mortality change	
					Diarr. (AxD)	Other (BxD)
	A	B	C	D	E	F
Constant	-1.55	2.39	2.30			
Borough pop.	0.33	0.06	0.10	48.0	15.8	2.9
Bor. Acreage	-0.03	-0.03	-0.03	30.1	-0.9	-0.9
RD Pop.	-0.03#	0.01#	-0.01#	34.8	-1.0	0.4
Housing	-0.12	0.02#	0.01#	62.6	-7.5	1.3
Children1-4	0.18	-0.01#	0.01#	-14.9	-2.7	-0.1
Fertility	0.15	0.32	0.33	-32.4	-4.9	-10.4
Food bundle	-0.11	0.04	0.01#	41.3	-4.5	1.7
Mothers'health (Female TB)	0.36	0.17	0.17	-69.4	-25.0	-12.0
1890s	0.03	0.01	0.01			
Port	-0.17	-0.09	-0.11			
Female empl.	0.25	0.12	0.15			
Miclass /suburbia	0.09	-0.19	-0.17			
No. Obs.	1296	1296	1296	Total	-30.7	-17.5
R^2(Adj)	0.69	0.82	0.84	Actual	-25.6	-15.2
DW	1.65	1.58	1.63			

Notes All variables in the regressions are measured in logs and *all* independent variables are statistically significant at the 5% level *except for those marked #.* The dependent variable is mortality of infants per 1000 births. The number of observations is 36 (years 1870-1905) x 36 (towns) =1296. Mothers' health is proxied by the mortality from tuberculosis per 1000 of females aged 15-44 . 'Female empl.' is a dummy for Preston and Leicester, two towns with exceptionally high female paid employment. Sanitation and water

supply had insignificant effects and are excluded since their inclusion would have restricted the range of observations. In column D the actual changes relate to the four years 1874-7 (that is 4x36 =144 observations) and 1903-6 (also 144 observations).

horse transport) were indeed special. Dummies are also used to pick up some of the effects of female employment. One version uses a 'textile' dummy covering Preston, Bradford and Leeds. Another proved more significant and this dummy, 'female emp.', includes Leicester and Preston only, in recognition of the point made earlier that levels of female employment in these towns were quite different from the other towns even those like Manchester and Nottingham where female employment was quite common. It is important to recognise that the smaller is the statistical role of the dummies the more are the major effects being captured by the main variables of the models.

What comes through strongly in the results is that a key vehicle of the decline in infant mortality was the improvement in mothers' health and the beneficial effects this had for the child. The increased availability of solid food, the decline in fertility and the increase in the housing stock also played a direct role - especially in the light of the continuing rise in population densities - but the improvement in mothers' health is quantitatively much more important. Table 7 reports regressions for infant mortality distinguishing diarrhoeal deaths from other sources of death. All variables are measured in logarithms so that the coefficient on female TB , the proxy for mothers' health, implies that a 10% improvement in mothers' health is associated, all other things being the same, with a 3.6% decline in the infant diarrhoeal death rate and a 1.7% decline in the infant mortality rate from other causes. This is the general relationship found for the whole sample of 36 towns over each of the years 1870 to 1905. It is instructive to see how far this helps in identifying the contribution to the average decline (over all towns) of 25 % in diarrhoeal mortality from the early 1870s to the early 1900s and the average decline of 15% in non-diarrhoeal mortality. It may be seen from the right-hand side of Table 7 that the female TB death rate itself declined by nearly 70% over the same period and , on its own, would thereby have reduced the infant diarrhoea death rate by 25% and the non-diarrhoeal rate by 12% (ninth row columns E and F).

Some factors were working in the other direction. The rising populations of the registration districts but especially that part within the (smaller) area of the municipal borough boundaries had a deleterious effect on infant mortality, offset in part by the rise in the housing stock. Table 7 reveals that these effects are wholly concentrated on diarrhoeal deaths and

had little impact on the other sources of death like the respiratory neo-natal diseases where the ability to thrive rather than the exposure to disease was important. The small coefficients on acreage may be reflecting its conflicting role : higher acreages will be associated with smaller population densities but also, in the more remote areas, with poor obstetric help. Expenditure on sanitation and water supply in the sample towns were included in some of the first regression runs but proved to have insignificant effects, probably, as we have argued before , because they do not rise to any significant levels until the turn of the century (Bell and Millward 1998, Millward and Bell 1998).

The inclusion of mothers' health in these regressions undermines the role of the food variable. This is to be expected since mothers' health here is standing in part as a proxy for the quantity and quality of breast feeding. Space precludes reporting the full regression work involved ; suffice to note that if the female TB death rate is not included the food variable has a very large coefficient. As Table 7 shows whilst the food variable is significant for diarrhoea deaths it has no effect on non-diarrhoeal deaths in the presence of the mothers' health variable. This is consistent with other U.K. evidence (Fildes 1991, 1992, Holdsworth 1997, Tanner and Mooney 1997, Huck 1994, 1997) that infants who died from non-diarrhoeal diseases were more likely to have been breast fed (and hence dependent on the mother) than infants who died from diarrhoea (who relied more on artificial foods).

Changes in fertility may be expected to have direct effects on infant mortality (over and above any indirect effects through mothers' health) by changing the number of susceptibles in the household and the amount of food available per family member. Family size is another way of gauging these effects and here the number of children aged 1 to 4 is included in the regressions (along with population) and does appear to be important at least for those deaths strongly associated with exposure to disease - the diarrhoeal diseases. Indeed other regression work (not reported here) shows, as one might expect, that the inclusion of family size or fertility reduces the impact of the housing and food variables (i.e total housing and total food per family). The variable for family size, children aged 1 to 4, of course reflects past fertility practices. The fertility variable in Table 7 reflects current fertility levels ; it emerges with a significant and independent role suggesting that it is picking up another factor identified earlier, the amount of time which mothers can devote to child care -

and this appears to manifest itself particularly in non-diarrhoeal deaths which would include neo-natal deaths.

The results reported in Table 7 therefore suggest that the factors we have identified go a long way to explaining the variations in infant mortality. They are able, as the right hand side of Table 7 shows, to account for much of the actual long term decline in infant mortality from the early 1870s to the early 1900s. The rise in population density in several towns would have caused infant mortality to rise but for large favourable movements in the housing stock, food availability, mothers' health, family size and fertility. Specifically they go a long way to explaining the large fall in infant mortality in the textile towns and in suburbia both of which witnessed significant decreases in fertility and in female deaths from TB as well as improvements in food and housing. It also explains the very small decline in infant mortality in the mining areas and the more or less average decline in rural areas (for which explanations have been largely absent in the literature).

There are several issues which cannot be accounted for by the variables identified so far. One is the level of infant mortality in suburbia, where it appears from the size of the dummy coefficient in Table 7 that the inhabitants may well have been imitating the behaviour of the healthy middle classes in the way Garrett and Reid (1995) have suggested. Further, the highly significant coefficient on the 'female empl.' dummy (which covers Preston and Leicester) suggests special factors associated with working conditions and child care operating directly from the employment setting. It is also of note that the '1890s effect' is present but small ; that is the 1890s pattern is not strongly inconsistent with the movement of the variables we have identified . Mothers' health, as will be seen shortly, also deteriorates in this decade. Finally diarrhoeal mortality in the ports appears to be significantly less that predicted by the model whilst showing no long run tendency to decline. In Swansea and Liverpool, infant mortality from diarrhoea rises not only in the 1890s but yet again in the early 1900s whilst in Sunderland, Southampton and Bristol the recovery in the early 1900s is not enough to put the level of the infant diarrhoea death rate below the level of the 1870s. For this we have no ready explanation. The only straws in the wind are that the decline in fertility in the ports was very modest and in Liverpool it actually rose in the 1900s and finished up higher than in the 1870s.

IX

Given the pivotal role Mothers' health, it is clearly important to know what are the main factors in determining its level and trends over time. Table 8 shows the results of a regression exercise for the 36 towns over the years 1870-1905 relating to females aged 15-44. It distinguishes the TB death rate, which is the proxy here for what the mother passes on to the child, from other sources of disease. The environmental variables - population densities, housing stock - are significant but nowhere near as important as they were in our earlier work on overall mortality levels (all ages, male and female combined ; Millward and Bell 1998). This is confirmation that the urban penalty is partly associated with working conditions outside the home which affected men, in the aggregate - more than women (McKeown 1962, Cronje 1984, Woods 1984). Food plays a very strong role, especially for the TB rate which again confirms prior expectations that these deaths are associated with nutritional state and resistance to disease. Fertility levels will affect mothers' health in part, as for infants, through the number of susceptibles in the house and in the amount of food available per family member. The family size variable (children 1 to 4) was tried in these regressions but added nothing to what already had been picked up by the fertility measure. This suggests a strong role for the other dimension of current fertility (as opposed to past fertility), namely the effect on the mother of a large number of conceptions and the associated general debilitation (Seccombe 1990. Reves 1985).

Since both food availability and fertility show unambiguously large changes from the 1870s to the early 1900s they played a central role in the improvements in mothers' health. Thus the very large fall in fertility in the textile towns is a key element in the substantial fall in infant mortality there. At the other extreme, the very small changes in fertility in the mining towns is consistent with the small decline in female mortality there. The quantified variables cannot account however for certain features of the level of female mortality. Thus the female TB death rate is some 25 % higher in rural areas (see farm dummy in Table 8) than predicted by the model and seems likely to be reflecting the low position in the family hierarchy which women had in these traditional settings and which does not seem to have been eliminated by the end

TABLE 8

REGRESSIONS FOR MORTALITY OF FEMALES AGED 15-44
(Sample of 36 Towns in England and Wales 1870-1905)

Independent Variables		TB	Other	Total	
Constant		0.31#	1.38	1.51	
Fertility	0.90	0.92	0.92		
Food bundle		-1.02	-0.50	-0.52	
Housing		-0.04#	-0.05	-0.05	
Borough pop.		0.16	0.21	0.21	
Bor. Acreage		0.01#			
RD Pop.		-0.14	-0.15	-0.15	
1890s		0.01#	0.01	0.01	
Port		-0.18	-0.13	-0.13	
Suburbia		-0.19	-0.27	-0.27	
Mining		-0.24	-0.11	-0.11	
Inland ind.			-0.09	-0.09	
Farm		0.25			
Female empl.			0.07		
No. Obs.		1296	1296	1296	
R^2(Adj)			0.62	0.64	0.64
DW		1.96	1.87	1.88	

Notes All variables are measured in logs and *all* independent variables were statistically significant at the 5% level *except for those marked #* (most of which were statistically significant at the 10% level). The dependant variable is the log of mortality of females aged 15-44 from tuberculosis (TB) or other causes or all causes. Proxies for sanitation and water

supply capacity proved not to be statistically significant and since data on these variables limited the samples slightly we have excluded them in the above.

of the century. The level of mortality in suburbia is well below that determined by the quantified variables and here again the cultural and educational characteristics of these towns is perhaps the explanation. What does remain something of a puzzle is why the level of female mortality in the ports, mining and inland industrial districts seems to have been well below that portrayed by the quantified variables of the model.

In all of the above fertility is treated as an exogenous variable but in reality its level is partly affected by mothers' heath and infant mortality. In the appendix a regression is run which takes this into account this simultaneity by developing a simple model of fertility. The results do not undermine the main conclusions of our research. Fertility differences across the sample of towns 1870 to 1905 seem to have been strongly associated with the cultural context with suburbia at one extreme and mining areas and catholic Liverpool. Lower fertility levels are associated with higher female employment levels, higher infant mortality, higher child survival rates, lower income levels and with seaside towns containing a high proportion of single females in service. Smaller influences were the price of tea (as a proxy for the cost of new consumer goods) and expenditure on schools (as a proxy for the rising cost of child training). Treating fertility this way, rather than as an exogenous variable, is shown in the appendix to be consistent with the central role of the mother as a medium for the long term decline in infant mortality.

X

The objective of this paper has been to draw out the central role played by mothers in the pattern of infant mortality in the Victorian period. The mother was a medium in the sense that her health crucially affected the three issues which determined the infant's life chances : the condition of the foetus, the quality of the immune system, the quality and quantity of breast feeding. Because the latter cannot be readily measured, we have proxied

their variations across regions and over time by a measure of female mortality. The research reported here reveals the range and quantifiable impact of mothers' health alongside the many other factors affecting infant mortality.

The differences in infant mortality across the sample of towns did narrow in the 1870-1914 period but they remained a dominant characteristic even at the very end in the early 1900s.. The results from our research suggest that, looking at the sample as a cross section, infant mortality was lower the smaller were house occupancy rates and population densities and the bigger was the purchasing power over food. Mothers' health had a powerful influence and this was itself strongly affected by real income levels as well as , in a small way, by environmental factors. Lower fertility levels had beneficial direct effects on infant mortality and sizeable indirect ones through mothers' health. These relationships hold for all comparisons across towns . Over and above that, high levels of female employment were associated with high infant mortality, and reinforcing that, poor mothers' health, The aspiring middle class in towns like Kingston-on- Thames, Tottenham and Oxford exhibited quite separate education and cultural influences on female mortality and fertility. In contrast the male mining culture as well as towns like catholic Liverpool had levels of fertility well above the average.

The conclusion about the pervasive average long term decline of infant mortality from the 1870s to the early 1900s is clear. There were some factors like rising population densities working against the decline in mortality. Opposed to that were a number of factors, the most powerful of which was the improvement in the health of females in the child bearing age range. This itself was most strongly affected by rising real incomes in terms of food which allowed better nutrition and by falling fertility rates. These factors are enough to explain much of the pattern of decline in infant mortality. No new factors are need be invoked, that is, to account for the very large fall in infant mortality in the textile areas and in suburbia nor the very small change in the mining areas. Real incomes rose strongly and fertility fell dramatically in the textile areas and in suburbia but by only small amounts in mining. In the middle range were the rural areas - typical, it turns out, of the average decline in infant mortality in the country as a whole and triggered by an average improvement in real incomes and fertility levels. Rising child survival rates were one of the factors which was pushing down the fertility levels but which came first cannot be decided by the present

model though the results reported here provide some clues for further research on this process.

APPENDIX

Although fertility is not the central focus of this paper, it can be misleading to take it as an exogenous variable when it is likely to be affected by, amongst other things, the levels of infant and female mortality. It is not enough however to simply develop and run a separate regression for fertility. This is a simultaneous equation system. There are three equations for infant mortality, mothers' health and fertility respectively. Each contains the others as independent variables as well as certain other variables exogenous to the system, like housing, food and population densities. There is then a danger of not being able to distinguish between the three equations unless they each have at least one truly exogenous variable not found in the other equations (the identity problem). This is solved in what follows by virtue of each equation having different dummy terms, by the presence of the variable children aged 1 to 4 in the infant mortality equation whilst the fertility equation contains 'time', educational expenditures and the price of tea as independent variables. A second problem can be illustrated with respect to the equation for infant mortality which, because it contains mothers' health and fertility as variables, is correlated with the disturbance terms in the equations for mothers' health and fertility. Hence the coefficients on fertility and mothers' health will be biased and inconsistent. A common way round this is to obtain an estimate for the three variables as functions of the truly exogenous variables in the system (like housing and food) and then feed these back into the original equations. The method of two stage least squares is used here.

The fertility model developed here draws on the extensive literature on the subject for the nineteenth century (Crafts 1984a, 1984b, Easterlin 1978, Garrett and Reid 1995, Lindert 1978, Seccombe 1990, Shorter 1977, Szreter 1996, Woods 1987). This invites the expectation that fertility will, other things being equal, be lower the higher are infant mortality and child survival rates given target family sizes. Higher family incomes (proxied here by the data on builders' wages) and lower food prices are expected to provide the material basis for larger families. Higher female wages and/or female employment is often interpreted as raising the 'cost' of having children. No comprehensive data on female wages in the sample towns are available but it is possible to approximate the effects of female employment by the use of dummies for the towns where female employment was high. A larger expenditure by local government on education (data for which are available from the Local Taxation Returns) may be taken as a proxy for the rising schooling costs associated with children in this period. It is possible also that whereas falling food prices lower the cost of feeding children, falling prices for new commodities might increase the attractiveness of allocating family resources away from the rearing of children. Here the price of tea is used as a proxy. Religion and other cultural influences on fertility practices are important and an attempt is made to gauge their impact by the use of dummies for town groupings which have these characteristics.

The results of the regression on fertility as well as the other elements of the two stage least squares model are shown in Table A.1. To a large extent the results for infant mortality and mothers' heath are similar to those in the main text. The only difference of significance is that the family size variable, children 1 to 4, comes out with a negative coefficient in the infant mortality regression. Effectively it offsets what is a very large coefficient on fertility. In the fertility model improvements in mothers' health (as reflected in lower TB rates) have the expected effect of raising fertility, other things being equal. However the association is not statistically significant so the effect does not

TABLE A.1
TWO STAGE LEAST SQUARES MODEL
INFANT MORTALITY, MOTHERS' HEALTH AND FERTILITY IN 36 TOWNS IN ENGLAND AND WALES 1870-1905

	DEPENDANT VARIABLES		
	Infant Mortality	Mothers' Health	Fertility
Constant	1.05	5.73	3.40
Borough population.	0.14	0.15	
Borough acreage	-0.03	-0.04	
Registration District Pop.	0.19	-0.08	
No. of houses	-0.03	-0.05#	
Number of Children 1-4	-0.20		
Mothers' health(female TB)	0.20		-0.04#
Wages	0.08	-1.77	0.35
Food prices	-0.02#	0.76	-0.25
Fertility	0.40	0.72	
Female empl.	0.13		-0.09
1890s	0.03	0.02	
Port	-0.12	-0.09	
Suburbia	-0.14	-0.08	-0.21
Mining		-0.16	0.21
Inland ind.		-0.07	
Infant mortality		-0.12	
Child 1-4 mortality			0.18
Price of tea			0.10
Education expend. per child 5-15			-0.001#
Seaside			-0.28
Liverpool			0.17
Time			-0.01
No. Obs.	1296	1296	1296
R^2(Adj)	0.82	0.60	0.68
DW	1.75	1.94	1.89

Notes All variables are measured in logs and *all* independent variables were statistically significant at the 5% level *except for those marked #.* Most of the variables and the data sources are described in the main text. 'Education expend.' is municipal borough expenditure on education for children aged 5 to 15. These data are taken from the Local Taxation Returns. The price of tea is derived from the same source and in the same way as food prices. 'Liverpool' is a dummy variable for the town. 'Time' is measured in years from 1870 to 1905 and hence varies from 1 to 36. Proxies for sanitation and water supply capacity proved not to be statistically significant and since data on these variables limited the samples slightly we have excluded them in the above. The number of observations is 36 (

years 1870-1905) x 36 (towns) =1296. For the two stage estimation procedure see Limdep Version 7.0 User's Manual , W.H. Greene, Econometric Software Inc. 1995, pp.371-2.

seem to be strong. Two dimensions of child survival rates are included in the fertility model. One of them, the mortality of children aged 1 to 4, emerges with a positive effect on fertility levels, which is what would be expected from theories of target family size. Lower infant mortality rates are however associated with higher fertility levels and, rather than reflecting targets for family size, may be reinforcing the links which allow healthy mothers to have fewer problems in child birth and care and subsequently to experience lower infant mortality levels.

Turning to the economic and social variables, larger family incomes and lower food prices are associated with higher fertility, other things being equal, whilst lower tea prices and more spending on education are associated with lower fertility, though the education variable is not statistically significant. The female population in the seaside towns of Blackpool, Ramsgate and Hastings included a high proportion of single women in service and the coefficient on the dummy variable suggests that the overall fertility levels in these towns was nearly 30% lower that in the rest, after allowing for all other factors. Some specific cultural influences can be found in the results for other dummies. High fertility levels are found in the strong male climate of the mining towns and in catholic Liverpool whilst very low levels are found amongst the aspiring middle class towns of suburbia. Although this model accounts for two thirds of the variation in fertility levels much of the explanatory power relates to cross section differences. It does not do so well in accounting for the secular decline in fertility and even the ‘time’ variable included to pick up other long term factors had only a small impact, suggesting scope for further work in this area.

REFERENCES

Atkins, P. J. (1992) 'White Poison? : The social consequences of milk consumption, 1850-1930' Society for the Social History of Medicine pp.207-27.

Bell, F.and Millward, R. 'Public Health Expenditures and Mortality in England and Wales 1870-1914' Continuity and Change 13(2), July 1998 (with F.Bell).

Board of Trade (1908). Report on the cost of living of the working classes, P.P., 1908 cvii.

Brown, J.C. (1997) 'Economics of infant mortality in German Towns, 1891-1912 : Issues for statistical analysis with some preliminary results' Paper presented to Conference on Health in the City, University of Liverpool, Sept..

Buchanan, I. (1985), 'Infant feeding, sanitation and diarrhoea in colliery communities, 1880-1911' in D.Oddy and D.S.Miller (Ed) Diet and health in modern Britain, Croom Helm.

Collet, C. (1898), 'The collection and utilisation of official statistics bearing on the extent and effects of the industrial employment of women', J.R.S.S., 61, pp.219-70.

Collis, E. L. (1940) ' Tuberculosis and influenza in relation to the World War, 1914-18' Tubercule Aug-Sept (Supplement).

Crafts,N. F. C. (1984a) 'A time-series study of fertility in England and Wales 1877-1938' Journal of European Economic History 13, 571-90.

Crafts, N. F. C. (1984b) 'A cross-section study of legitimate fertility in England and Wales 19118' Research in Economic History 9, 89-107.

Cronje, G. (1984) 'Tuberculosis and mortality decline in England and Wales, 1851-1910' in R. I. Woods and J. F. Woodward (Ed) Urban Disease and mortality in 19th century England., Batsford.

Dyehouse, C.(1978), 'Working class mothers and infant mortality in England, 1855-1914' Journal of Social History vol. 12, pp. 248-266.

Easterlin, R. A. (1978), 'The Economics and Sociology of Fertility : A Synthesis', in C. Tilly (Ed), Historical Studies of Changing Fertility, Princeton University Press.

Fildes, V. (1991) 'Breast feeding practices during industrialisation 1800-1919' in F. Faulkner (Ed) Infant and child nutrition world wide : Issues and perspectives CRC press.

Fildes, V. (1992) 'Breast-feeding in London, 1905-1919' J.Biosoc.Sci. vol. 24, pp. 53-70.

Garrett. E. and Reid,A. (1994) 'Satanic Mills, Pleasant Lands : Spatial Variation in Women's work, Fertility and Infant Mortality as viewed from the 1911 census' Historical Research vol. 67.

Garret, E. and Reid, A.(1995) 'Thinking of England and taking care : family building strategies and infant mortality in England and Wales' International Journal of Population Geography 1, 69-102.

Graham, D.(1994) 'Family employment and infant mortality : some evidence from British towns, 1911,1931,1951' Continuity and Change 9(2), pp.313-46.

Hardy, A. (1992) ' Rickets and the Rest : child care, diet and the infectious children's diseases, 1850-1914' Society for the Social History of Medicine.

Harrison, B. (1995) 'Women and health' in J. Purvis (Ed) Women' History : Britain, 1850-1945 UCL Press.

Holdsworth, C. (1997) 'Women's work and family health : evidence from the Staffordshire Potteries 1890-1920' Continuity and Change Vol 12, pp.103-28.

Huck, P.(1994)'Infant Mortality in nine Industrial Parishes in Northern England 1813-1836' Population Studies vol.48, pp.513-26.

Huck, P.(1997) 'Shifts in the seasonality of infant deaths in nine English towns during the nineteenth century ; a case for reduced breast feeding?' Explorations in Economic History 34, pp.368-86.

Humphries, J. (1995), 'Women and paid work', in J. Purvis (Ed) Women' History : Britain, 1850-1945 UCL Press.

Kemmer, D. (1997), 'Investigating Infant Mortality in Early Twentieth century Scotland Using the Civil Registers : Aberdeen and Dundee compared' Scottish Economic and social History, pp.1-19.

Kintner, H. J (1985) 'Trends and regional differences in breast feeding in Germany from 1871 to 1937' Journal of Family History Summer.

Kintner, H. J. (1988) 'Determinants of temporal and areal variations in infant mortality in Germany, 1871-1933' Demography 597-609

Lee, C. H. (1991). Regional inequalities in infant mortality in Britain 1861-1971 : patterns and hypotheses. Population studies 45, pp.55-65.

Lewis, M. (1979) 'Sanitation, Intestinal Infections and Infant mortality in Late Victorian Sydney' Medical History vol. 23 pp.325-38.

Lindert, P. H. (1978), Fertility and Scarcity in America, Princeton,N.J, Princeton University Press.

Local Government Board (1871-1915). Annual Local Taxation Returns for England and Wales .

Loudon, I. (1988) 'Maternal Mortality : 1880-1950. Some Regional and International Comparisons' Society for the Social History of Medicine Vol. 1(2) pp.183-223.

Medical Officer of Health to the Local Government Board (A.Newsholme 1910) 'Infant and child mortality', Report of the Medical Officer of Health of the Board for 1909-10, Annual Report of the Local Government Board 1909-10 (Supplement) Command 5263.

Medical Officer of Health to the Local Government Board (A.Newsholme 1912/13) 'Second Report on Infant and Child Mortality' Report of the Medical Officer of Health of the Board for 1912-13, Annual Report of the Local Government Board 1912-13 (Supplement) .

Millward, R. and Bell, F. (1998), 'Economic Factors in the Decline of Mortality in late 19th and 20th. Century Britain' European Review of Economic History ,2 (December), 1998, pp.263-288.

Mitchell, B. R. (1988), British Historical Statistics, Cambridge : Cambridge University Press.

Morgan, N. (1999), 'Infant mortality, flies and horses in later nineteenth century Preston' mimeo.

Registrar-General (1861-1913). Annual and Decennial Reports.

Reher, D. (1999) 'Back to basics : mortality and fertility interactions during the demographic transition' Continuity and Change.

Reid, A. (1999), 'Estimating the influences on infant and child mortality ; a hazards model example', paper presented at Workshop on Infant Mortality, History Department, University of Manchester, March.

Reves, R.(1985)'Declining Fertility in England and Wales as a major cause of the Twentieth century decline in mortality' American Journal of Epidemiology ,122(1), pp.112-26.

Seccombe, W. (1990) 'Starting to stop : working class fertility decline in Britain' Past and Present 126, pp.151-188.

Szreter, S. (1996) Fertility Class and Gender Cambridge University Press .

Szreter, S. and Mooney, G., (1998), 'Urbanisation, mortality and the standard of living debate : new estimates of the expectancy of life at birth in nineteenth century British cities' Economic History Review ,vol. LI(1), Feb.

Tanner, A. and Mooney, G. (1997)'Infant mortality in Kensington 1890-1914' Paper presented to Conference on Health in the City, University of Liverpool, Sept..

Tomes, N.(1990) 'The Private side of Public health : sanitary science, domestic hygiene and the germ theory 1870-1900' Bulletin of the History of Medicine vol. 64, pp.509-39.

Vallin, J. (1991) 'Mortality in Europe from 1720 to 1914 : long term trends and changes in patterns by age and sex', in R.Schofield, D.Reher and A.Bideau (Eds). The decline of mortality in Europe , pp.39-67, Oxford, Clarendon Press.

Watterson, P. A. (1986), 'Role of the Environment in the Decline of Infant Mortality : An Analysis of the 1911 Census of England and Wales' J.Biosoc.SCi. (18), pp. 457-470.

Williams, N.(1994) 'Death in its Season : Class, environment and the mortality of infants in Nineteenth century Sheffield' Society for the Social History of Medicine pp.71-94.

Williams, N. and Galley, C. (1995) 'Urban-rural differentials in infant mortality in Victorian England' Population Studies vol. 49, pp401-20.

Williams, N. J. and Mooney, G. (1994) 'Infant mortality in the age of great cities : London and the English provincial cities compared c.1840-1910' Continuity and Change 9, pp.185-212.

Woods, R. I. (1984), 'Mortality patterns in the nineteenth century' in R.I.Woods and J.H.Woodward (Eds). Urban disease and mortality in the nineteenth century London : Batsford, pp.39-64.

Woods, R. I. (1987) 'Approaches to the Fertility Transition in Victorian England' Population Studies 41, 283-311.

Woods, R. I., Watterson, P. A. and Woodward, J. H.(1988/9) 'The causes of rapid infant mortality decline in England and Wales, 1861-1921' Part I, 1988, Population Studies 42, pp.343-68, Part II, 1989, Population Studies ,34, pp.113-32.

Woods, R. I, and Woodward, J. H. (Eds). Urban disease and mortality in the nineteenth century London : Batsford, pp.39-64.

Wray, J. D.(1978) 'Maternal Nutrition, Breast feeding and infant survival' in W. H. Moseley (Ed) Nutrition and Human Reproduction .