A SIMULATION OF THE IMPACT OF CHANGES IN AGE

AT MARRIAGE BEFORE AND DURING THE ADVENT OF

INDUSTRIALISATION IN ENGLAND[*]

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The last three decades have seen a vigorous debate over the nature
of pre-industrial European demographic conditions and the population changes
of the eighteenth and early nineteenth centuries.   The controversy has been
especially hard fought in the case of the English experience. [1]   It is
generally agreed that prior to about 1750 national rates of population growth
rarely exceeded zero by much over periods as long as a century, but what is
much disputed is the extent to which this absence of rapid population expansion
should be attributed (in Malthusian terminology) to preventive or to positive
checks.   The prolonged nature of the controversy is, of course, largely due
to acute data problems.

The orthodox wisdom of the 1940's and early 1950's emphasised positive
checks, usually in the context of the Theory of the Demographic Transition, with
the implication that variations in mortality were the main determinants of
population change before and during the demographic revolution.   This position
has been well summarised by one of its opponents :

> "The birth rate was determined by the force of natural instincts;
> these were modified by custom, but, since custom was tenacious,
> birth rates were not liable to much change.   It was the death rate
> which varied and by its variations determined the size of the
> population; it was variations in the death rate which adjusted
> the population to the means available for supporting human life ...
> High death rates were a consequence of high birth rates and, in
> Hecksher's phrase, 'Nature audited her accounts with a red pencil'.
> This was the primitive equilibrium in which population growth was
> principally determined by what Malthus called the positive checks." [2]

This position has been strongly challenged on a number of grounds.

Some writers have emphasised the stochastic component in mortality rather than the predominance of the Malthusian subsistence crisis; for example, Chambers argues that :

> "The outstanding factor that emerges from this inquiry is the biological one, the utter dependence of the pre-industrial population, even in the absence of Malthusian pressures, on the fortuitous movement of natural forces."[3]

Hajnal, stressing a preventive check, maintained that from at least the seventeenth century onwards there existed a distinctive Western European marriage pattern characterised by late marriage and substantial celibacy with the corollary that a smaller fraction of the population was vulnerable to subsistence crises than would otherwise have been the case. [4]

More recently further preventive checks have been hypothesised in terms of changes in fertility, brought about by changes in age at marriage primarily, but birth control within marriage also, acting to achieve a homeostatic adjustment mechanism to keep population growth in line with the growth of resources. Fertility changes it is argued may have acted to reduce or even eliminate the impact on living standards of intrinsic changes in mortality and to decrease reliance on positive checks. Thus Wrigley suggests :

> "It would be surprising if there were not present in pre-industrial European populations a range of possible courses of social action which could secure a stabilisation of numbers well short of the appalling conditions of control envisaged at times by Malthus ... in pre-industrial English society a very flexible response to economic and social conditions was possible ... populations {may have} behaved in a manner more

likely to secure optimum than maximum numbers {for} the
establishment and holding of gains in real income."[5]

On occasions fertility changes might be instrumental in the establishment of

a new equilibrium relationship between population and resources; Habakkuk

surmises :

"When population increased much more or less than resources,
changes in births and deaths were set in motion which tended
to bring them into line. But there might also be set in
motion longer term social changes which might permanently
shift the relation between people and resources."[6]

Both these writers are very cautious and acknowledge the existence

of regional variations in the relative importance of these factors compared

with positive checks, lags and imperfections in the equilibrating mechanism and

the possibility that fortuitous events may dominate demographic changes in the

short term. [7] Nevertheless their views have been sharply criticised by

writers wishing to re-establish the validity of the traditional density dependent

mortality position of the Demographic Transition theorists. McKeown, Brown

and Record have asserted that before the European demographic revolution :

"the size of human populations had been limited ... mainly by
lack of food ... nothing in past or present day experience,
so far is known, suggests that restricted reproduction was a
major influence on population size ... over any considerable
period there is little reason to doubt that mortality was
determined mainly by the related influences of food shortage
and disease, particularly infectious disease."[8]

Some of the differences between these positions can be illustrated

with the aid of a diagram presented by Lee [9] and reproduced as figure 1.

This diagram represents a special case and can be thought of as relating to an economy in a stationary state. The economy has given technology and factors of production other than labour are fixed; equilibrium population growth rate is zero, i.e. at the intersection of the fertility and mortality schedules. The diagram depicts the comparative statics of an exogenous change in mortality regime from level (1) to level (2). The magnitude of its impact on population size and real wages depends on the elasticity of fertility

Figure 1.

Fertility
Mortality
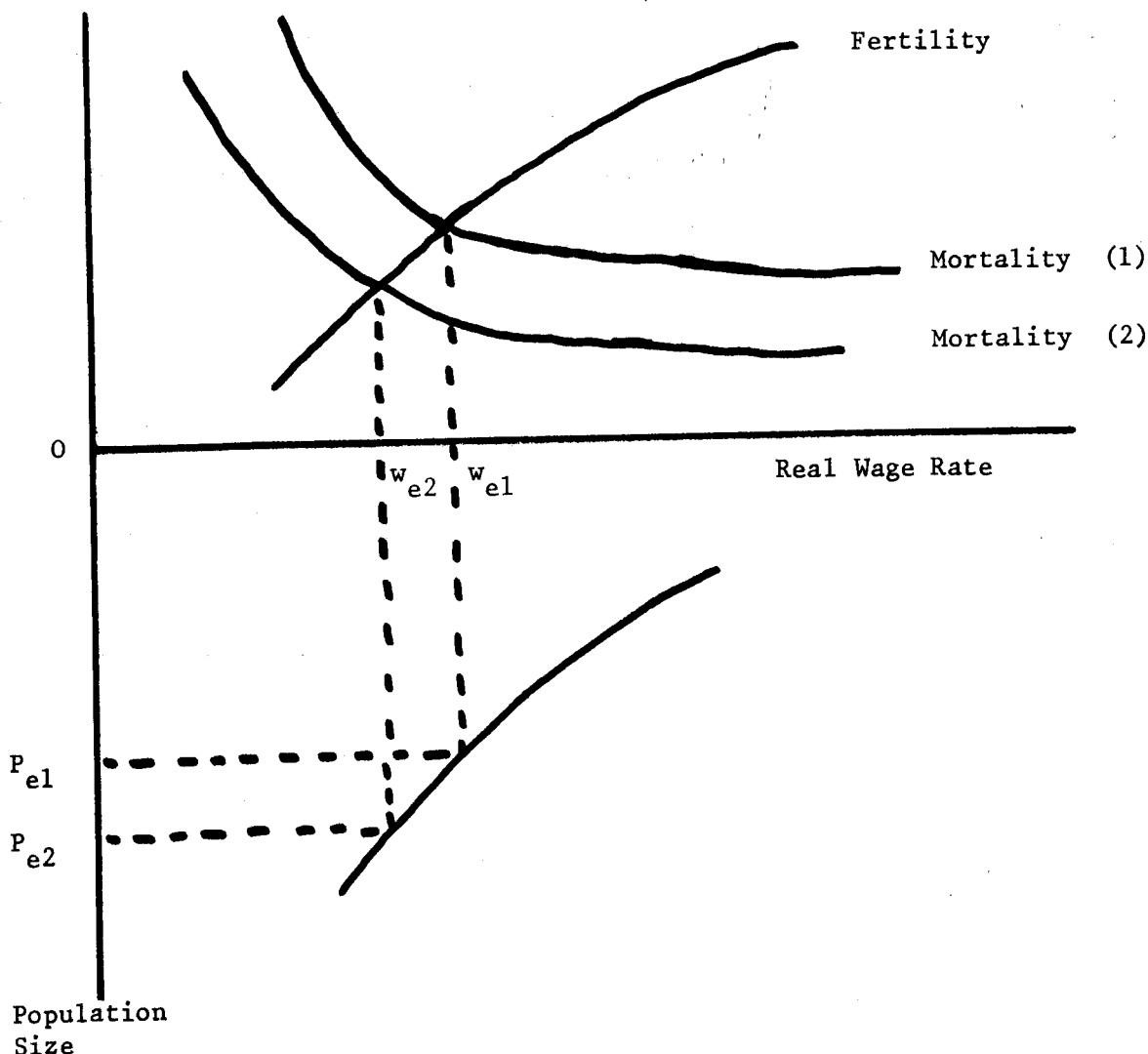
with respect to the real wage rate, the key feature of the diagram. As

a first approximation the writers above can be regarded as disagreeing over

the value of this parameter. Evidently in the limiting density dependent

mortality case the schedule will be horizontal, fertility will be constant,

mortality conditions will determine population size and real wages and a new

equilibrium will still have reliance on positive checks at an unchanged crude

death rate. On the other hand in the limiting case of perfectly successful

preventive checks the schedule will be vertical, population size and real

wages will be invariant with respect to the mortality regime, the exogenous

improvement in mortality conditions will be reflected in a lower crude death

rate and the whole burden of adjustment is borne by fertility. Lee estimated

a model of this kind for pre-industrial England and found that :

> "equilibrium values ... {of population size and real wages}
> were not constant, but rather depended sensitively on the
> exogenously fixed secular level of mortality."

Finding a low value of about 0.4 for the elasticity of fertility with respect

to the real wage he concluded that :

> "social control of population size and the level of living
> was very weak."[10]

In a more general model applicable to a growing economy such as

Britain after 1750 certainly was, the role of preventive checks might then

be expected to be to establish an equilibrium but positive rate of population

growth and hence (in terms of ex-post accounting identitites) to establish the

rate of growth of per capita income for any given growth rate of income. In

either case the importance of the shape of the fertility schedule directs attention to its underlying determinants :

(1)   Behavioural responses to changes in real wages

(2)   Efficacy of family limitation strategies either of contraception within marriage or changes in age at marriage.

We reported in an earlier paper some results concerning the plausibility of the evidence for contraception within marriage in terms of its implications both for required changes in family size targets and for required contraceptive effectiveness. [11] The purpose of this paper is to examine the likely impact of changes in age at marriage on fertility. This involves addressing two kinds of question.

(1)   Could changes in age at marriage have been important in influencing levels of fertility or more generally rates of population growth in pre-industrial Europe?

This can be split into two parts; by how much would age at marriage have needed to change to achieve a given change in (a) average family size and (b) population growth and secondly, how sensitive is this estimate to the kind of mortality regime which existed?

(2)   Were changes in age at marriage actually important for fertility and population growth in a particular historical situation? In this paper we consider the particular example of Britain in the period 1700-1850, probably the historical

case for which the importance of changes in age at marriage has been most
disputed.

On the first of these questions we also find marked disagreement.
Eversley for instance asserts that :

"the general age of marriage in Europe did not change much
in the last three hundred and fifty years and ... large changes
would be required to ensure an increase in marital fertility," (12)

whilst Wrigley on the other hand claims that :

"the changes in mean age at marriage alone provided scope for
a very wide range of rates of increase (or decrease) of
population." (13)

McKeown and Brown have argued that in high death rate communities
such as pre-industrial Europe a fall in age at marriage will have very little
effect on population growth because it requires about 5 years' fall to produce
one extra child per family and, because this would lead to more large families
in an era where infant mortality rises steeply with parity, the increase in the
number of surviving children would be slight. (14)   Habakkuk, however, thinks
that only about 2½ years' fall in age at marriage would be required to produce an
extra child and that taking into account the effect of adulty mortality in
curtailing the childbearing period of a marriage this could bring about a rise of
perhaps 0.3% in the rate of growth of population. (15)

These opinions are not really very satisfactory.   They vary enor-
mously about the impact of age at marriage on live births, one deals with parity

specific infant mortality but not adult mortality whilst the other does the

opposite. In any case both arguments overlook a number of important complex-

ities in modelling the impact of age at marriage and are suspect in their use

of data to make crude estimates.

These difficulties are examined in Section II of this paper where

a rationale for simulation techniques as a method of resolving them is presented.

The model is outlined, the required data discussed and the adequacy of the model

in the context of pre-industrial European evidence is considered in Section III.

Results relevant to the general question of the potential of age at marriage

to affect fertility and population growth are presented in Section IV and the first

half of Section V, whilst in the latter half of that Section we review the debate

over the role of age at marriage in the English demographic revolution in the

light of our general findings. Finally in Section VI we summarise our conclusions.

II.

The review of the literature undertaken in Section I revealed a wide difference of opinion concerning the effect of a change in age at marriage on family size. This is not surprising as there are a number of serious difficulties with the methods which have been used for estimation, all of which have been based on indirect evidence.

The commonest procedure has been to compare completed family size in terms of live births, that is family size for those marriages which survived until the wife was 45 years old, for women in a given cohort who married at different ages. That comparison is then used to derive an estimate of the average number of children foregone by a years delay in marriage for women in a non-contracepting population. This is the basis for both Habakkuk's and McKeown and Brown's estimates reported above. Two straightforward problems often crop up with this procedure and are applicable to these cases.

(1)   Ages at marriage for historical communities are frequently only available as grouped data, (partly because of small samples problems); thus McKeown and Brown obtain their estimate of 0.2 children foregone per year from data showing completed family size for women in late nineteenth centure rural Ireland as 8.81 at age of marriage less than 20 years, 8.04 at 20-24, 6.79 at 25-29 and 5.57 at 30-34. [16] No information is given about the distribution of ages at marriage within these age groups and hence a serious possibility of bias in the estimate arises.

(2)   Better data tends to be available in situations when there is a

good chance of distortion through some kind of control of births being attempted;

this may be a difficulty with Dunlop's analysis of late nineteenth century

Scottish data on which Habakkuk's estimate is based. [17]

There is also another potentially more serious problem, that is that

there exists a high degree of association between natural fertility and age at

marriage.   This could arise for example from selective postponement of marriage

or by a substial proportion of shotgun weddings occurring, (those with a high

monthly chance of conception (MCC) [18] having a greater chance of pre-marital

pregnancy).   These possibilities are worth considering;   for example Hair [19]

found 15% of brides pregnant in seventeenth century England, a proportion which

more than doubled in the following century, whilst Kennedy found for Ireland in

the period from which McKeown and Brown's results come :

> "... that the selectivity of who postponed marriage is not an
> independent variable, we cannot say for certain how much it must
> be reduced to produce an extra child per union." [21]

The importance of this point is reinforced by consideration of an

alternative method of estimating the effect of age at marriage on family size,

namely a cross-section analysis of the results of family reconstitution studies

of different village communities in pre-industrial Europe.   Using this approach

Scott-Smith found that :

> "If a hypothetical sample had the same male marriage age and a
> female age at marriage one year later than average, the total
> marital fertility in this village would be 9.58 children compared
> to the 8.99 average [22] ... Although earlier marriage produces
> a larger complete family size for individual couples, this obvious
> result does not hold for the group." [23]

The explanation for this paradoxical result would seem to be that areas with higher natural fertility developed customs of later marriage as a preventive check, the differences being sustained by a high degree of geographical endogamy. It seems likely that the same sort of response may have characterised the behaviour of particular groups of marriages within the communities for which we have data on completed fertility at different marriage ages.

The implication of the preceeding discussion is the chance that the samples of women married at different ages in a given cohort are not drawn from the same reproductive population. A priori the possibility of bias but its extent and direction are unclear, e.g. do preventive checks dominate shotgun weddings?

However, there is a much more basic reason why these methods of estimating the implications for fertility of a change in age at marriage may give biased results. They are based on inference from an empirical association between age at marriage and family size and do not consider the intervening structure of inputs to the reproductive system. In the absence of contraception completed fertility will depend on age at marriage, age at permanent sterility and intervals between births. These last are made up of several components - pregnancy, pregnancy wastage, amenorrhea, anovulatory cycles and time while susceptible spent waiting to conceive, (which depends on MCC). In general each of these may vary between women or over time and may change in response to a movement of mean age at marriage. The existence of these largely non-observable inputs to the reproductive system makes inference from observed statistics of the type favoured by Habakkuk and McKeown and Brown a hazardous procedure. [24]

For example, suppose MCC is a distribution, infant mortality is parity specific and the length of amenorrhea depends partly on the survival of the new born child. [25] Then to assess the effect of a change in marriage age on fertility it is necessary to take into account the resultant change in the distribution of completed family size, which will affect and be affected by infant mortality which is parity specific, and which depends on any related change in the degree of association between MCC and age at marriage. Now infant mortality impinges on birth intervals and hence completed fertility through amenorrhea and this effect will be more powerful on the average for the more fecund who will also tend to become pregnant again sooner etc., etc. In other words there are a wide variety of offsetting effects and feedbacks such that there is no guarantee at all that the result of an actual change in age at marriage will match the inference drawn from cohort fertility at different ages at marriage. Furthermore since many of these inputs in this stochastic process are either age or parity specific an analytical solution from a probability model is ruled out.

In order to deal with the relationship between changes in age at marriage and population growth we have to contend with further complicating factors. Adult mortality (which is itself age specific) has to be introduced. It is important to know how the distance between generations is affected [26] and whether the change in marriage patterns alters the proportion ever married.

We argue then that to investigate the potential strength of changes in age at marriage in influencing family size or demographic growth, and hence for operating as a powerful preventive check in a homeostatic adjustment process,

it is necessary to consider the relationships between the sets of inputs
of non-observable behavioural parameters and distributions in the reproductive
system and the outputs of observable fertility experience.   It is our thesis
that this can be aided by the construction of a simulation model.

        We have presented the case for this position is some detail elsewhere;
(27)   we therefore merely offer a summary argument here.   The main advantages
of the approach are that age and parity specificity can be dealt with and hence
a more "realistic" model is possible than would otherwise be the case.   Further-
more results can be obtained from controlled experiments under different demo-
graphic regimes, in particular enabling association between age at marriage and
fecundity to be controlled for, and the sensitivity of the results to alternative
assumptions about the magnitudes of non-observable inputs can be examined.

III.

The model we have used to assess the impact of a change in age at marriage on fertility levels is an extension of one that we have described in detail elsewhere. [28] We will limit ourselves here to a summary description, apart from a fuller statement concerning new facilities.

The simulation consists of entering a cohort of women singly as an input into the model. The women vary according to independent marriage and mortality distributions and differing lifetime profiles of MCC. The process of generating births and deaths of children during the fertile lifetime of the marriage is then carried out via a large number of stochastic processes including conception, occurrence of miscarriage or stillbirth and duration of amenorrhea. The fertile lifetime of the marriage is determined by the death or permanent sterility of one of the partners.

There are two major new facilities included in the model to allow an investigation of some of the questions raised in the preceeding sections. First, it may be argued that there exists a negative relationship between the age at marriage and MCC. We considered the direct inclusion of premarital sexual experience in the model in order to derive such a relationship, but concluded that too much unobtainable information was required. We would need to know the age distribution and density of such experience together with the association between them and MCC. We eventually abandoned this approach in favour of arbitrary linear rank correlations between age at marriage and MCC. We chose two extreme cases in which the values of the rank correlation coefficient (ρ) were 0 (independence) and -1 (perfect negative rank correlation) respectively. We could then if necessary "mix" samples of the two extreme cases according to pre-determined

proportions. However, as we will argue in Section IV that changing ρ from 0 to -1 does not produce a very large impact on measures of the sensitivity of fertility to changes in the marriage distribution, we have mainly limited our analysis to the extreme cases.

The second new facility in the model is the inclusion of parity specific infant mortality rates. This simply allows infant mortality to vary according to the number of previous children born in the family. As noted in Section I increases in infant mortality with the parity of the mother were regarded by McKeown and Brown as an important reason why changes in age at marriage would be ineffectual in raising the number of surviving children or the rate of population growth, although this argument has been largely ignored by other participants in the debate. The contention that infant mortality rose sharply with parity has recently been challenged by Cohen, who, using a hierarchical log-linear technique, found no association between birth order and infant mortality in three pre-industrial European communities. [29] The difficulty with observed data, especially that relied on by McKeown and Brown which does not control for sibship size, is to separate the influence on infant mortality of family size, (and associated variables such as income, social class etc.,) from that of birth order given family size, the case relevant to McKeown and Brown's arguments. For example, in developed countries observations at higher parities may be dominated by groups subject to relatively high infant mortality.

In our view then the degree of parity specificity in infant mortality in pre-industrial Europe remains doubtful. Accordingly we report in our experiments results from cases where parity specificity is very slight, based on

empirically observed results for contemporary Bangaladesh (S-C) [30], and

also two artificial cases, "medium" and "high", which are loosely based

on results for poor mothers under 25 in 1947 in Birmingham, England, given

by Gibson and McKeown [31] and cited with approval by McKeown and Brown.

These values were adjusted to give mean infant mortality approximately

consistent with U.N. Life Tables level 20 ("high") and level 50 ("medium").

A diagram showing the logic of the model including new facilities

is given in figure 2. The artificial parity specific infant mortality rates

are given in Table 1.

Table 1.   Artificial Parity Specific Infant Mortality Schedules

Parity:	0	1	2	3	4	5	6	7 and over
"medium"	.1	.1	.1	.2	.2	.3	.3	.4
"high"	.1	.1	.2	.2	.4	.4	.6	.6

Note : figures are probabilities of death by the end of the third month

Figure 2
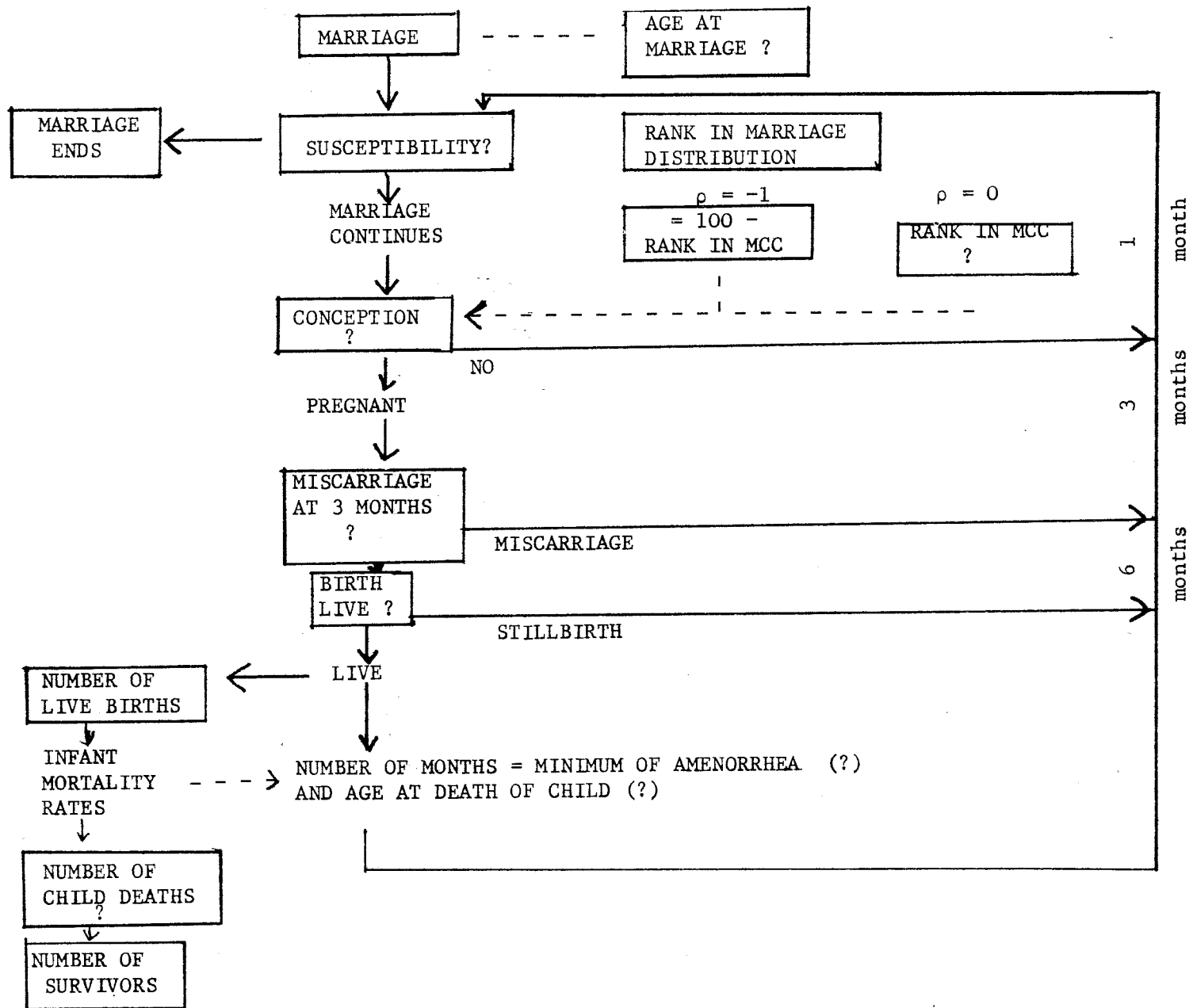
As can be seen from figure 2, a considerable amount of other data is required to simulate the model. The MCC distribution is the Distribution II of Crafts and Ireland, (op.cit., 1974). Base decile values and time profiles are given in Table 2. The mean MCC of women at 20 years, 30 years and 40 years of age is 0.262, 0.176 and 0.088 respectively.

Table 2. Monthly Chance of Conception

Deciles of MCC ranking distribution	0	1	2	3	4	5	6	7	8	9	10
x	0	.058	.075	.094	.106	.125	.138	.150	.175	.213	.375

Note: $MCC = \{2-2(240-t)/540\}x$ $,t \leqslant 240$

       $= \{2/3 + 4(480-t)/720\}x$ $,240 < t \leqslant 480$

       $= \{2(540-t)/180\}x$ $,480 < t \leqslant 540$

       $= 0$ $,t > 540$

where t is the age of the women in months, and where the value of x specific to her is determined by her ranking in the MCC distribution.

Data inputs concerning amenorrhea, stillbirths, miscarriages and permanent sterility are as given in Crafts and Ireland, (op.cit., 1975) and are not likely to be crucial to present purposes. Marriage and mortality distributions are, however, of central importance. [32] In the experiments reported here we have confined ourselves to U.N. Life Tables levels 50 ($^{o}e_{o} = 45$) and 20 ($^{o}e_{o} = 30$) for mortality regimes. These broadly fit in with the artificial parity specific infant mortality "medium" and "high" schedules respectively,

although the distribution of family sizes, which is sensitive to the choice

of marriage distribution, will of course affect this compatibility.   The

S-C infant mortality rates do not seriously conflict with the level 50 table.

The life table levels 20 and 50 represent respectively a putative minimum

and a putative maximum life expectancy for Europe in the period 1700-1850.

The levels were chosen in accordance with the evidence summarised in Glass. [33]

We have used a variety of marriage distributions, but describe

here only those for which we report experiments in the next Section.   In all

cases we make the simplifying assumption that the ages at marriage of

husband and wife are the same.   The simplest age at marriage distributions

considered are those based on an identical age at marriage for all marriages

in the sample.   Two ages - 23 years and 28 years - constitute two such

distributions.   We summarise in Table 3 distributions of age at marriage

conditional on being married by age 45 based on empirical work by Hollings-

worth [34] and on the standard marriage distributions of Coale. [35]   The

latter has a key parameter K.   Average age at marriage   (F)   for all

distributions is given.   A further requirement for the study of changing

marriage patterns, the proportion of women never married at age 45 is not

considered until Section V.

Table 3. Cumulative Probability of First Marriages occurring before
          Age t given they occurred before Age 45 years

Marriage Distribution	K1(i)	H1	H2	K2(ii)
Source	Coale K=3/4	Hollingsworth 1700-24	Hollingsworth 1800-24	Coale K=5/4
5 = 15	0	0	0	0
19	.13	.16	.03	.04
23	.54	.47	.34	.23
27	.80	.70	.63	.50
31	.92	.84	.83	.72
35	.97	.91	.91	.84
39	.99	.96	.96	.93
43	1.00	.99	.99	.98
45	1.00	1.00	1.00	1.00
F	23.60	24.87	26.23	28.02

Notes :   (i)   In terms of Coale's notation a = 15, C = 1
           (ii)   In terms of Coale's notation a = 15, C = 20/19

Similar data inputs have successfully simulated evidence documented for the English parishes of Colyton and Moreton Say. [36] In order to establish further the reasonableness of our data we simulated marriage distributions H1 and H2 for marriages between 15 and 25 years of age. Average births within 5, 10, 15, 20 and 25 years of marriage date were calculated. These were compared with the average to be expected on the basis of the mean age specific marital fertility rates computed by Scott-Smith from 38 Western European reconstitution studies, the data from which mostly concerns the eighteenth century. [37] The results for the H2 distribution, which are typical, are reported in Table 4.

Table 4.   Comparison of Simulation Results with Actual Evidence for Eighteenth Century Europe

	Births 0-5yrs	5-10yrs	10-15yrs	15-20yrs	20-5yrs
Actual	2.30	2.12	1.77	1.20	0.40
Simulated	2.15	2.17	1.79	1.54	0.62

The orders of magnitude seem acceptable and add confidence to the use of the model for the analysis of changes in distributions and parameters. Table 4 also provides some base for comparison with regard to the seriousness of the alleged biases discussed in Section II which are investigated in the following Section.

The simulation results are of course based on the assumption of

no relationship between fertility and time since marriage; this assumption is retained in the next Section to permit a measurement of the "pure" impact of changes of age at marriage. In practice of course the intervention of contraception reduces the impact of age at marriage in most societies, quite possibly including pre-industrial Europe, [38] but in terms of the homeostasis hypothesis it seems useful to proceed in this way and find maximal impacts of marriage distribution shifts.

IV

We present the results of this Section in terms of three experiments. Experiment 1 includes preliminary simulations of variations in age at marriage distribution in the absence of parity specific infant mortality to test the possible significance of an age at marriage/MCC correlation. Experiment 2 consists of an attempt to gauge the quantitative importance of parity specific infant mortality from the point of view of the reaction of average infant mortality to a change in the age at marriage distribution, in the framework of the simplest age at marriage distributions. Experiment 3 represents the amalgamation of these two lines of enquiry and incorporates the effect of the presence of parity specific infant mortality on fertility in the event of shifts between the age at marriage distributions of Table 3. This is extended in Section V to consider the sensitivity of rates of growth of population to these changes.

Experiment 1

We consider three cohorts each of 100 women. The first cohort all marry at age 20, the second at age 25 and the third at age 30. The underlying marriage distribution is assumed to be H1 and all marriages are assumed to survive until eventual permanent sterility, (i.e. adult mortality is ignored and average births relate to completed rather than actual family size). Simulations were performed both with $\rho = 0$ (case(a)) and $\rho = -1$ (case (b)) and the results are shown in Table 5.

From Table 5 cases (a) and (b) it is seen that observations of the different age at marriage groups yields an estimate of children lost per year delay in marriage of $.44\lambda + .87(1-\lambda)$ for ages 20-25 and of $.43\lambda + .55(1-\lambda)$ for ages 25-30, where λ is the proportion of the population with $\rho = 0$ and $1-\lambda$ that with $\rho = -1$.

Table 5.   Results of Experiment 1

Case	(a)	(b)	(c)	
Age at Marriage of Cohort (years)	$\rho = 0$	$\rho = -1$	$\rho = -1$	$\rho = -1$
			MCC of those now married at age 20	MCC of those now married at age 25
20	9.35	10.90	10.90	-
25	7.16	6.54	8.52	6.54
30	5.00	3.77	-	4.77
Children lost per year by rise from 20 to 25 years	.44	.87	.48	-
Children lost per year by rise from 25 to 30 years	.43	.55	-	.35

However, these estimates of the coefficients for the $1 - \lambda$ group are biased upwards for the actual impact of a change in marriage distribution would be recorded by considering cases (a) and (c). [39] Case (c)

considers the difference in family size of the highest MCC group if marriage

is delayed, whereas case (b) takes the difference in family size between

that of the highest MCC group marrying at age 20 and a lower MCC group marrying

at age 25. It seems unlikely that this bias will be large though since in

practice λ would almost certainly be in excess of 0.8. Hence the use of

observed statistics which will be a mixture of (a) and (b) rather than

(a) and (c) in actual historical data should not be too misleading on this

account, especially if λ is very close to 1. We will return to comparisons

of estimates under case (a) and case (c) in Experiment 3.

We must point out here that we do not allow for pregnant brides

explicitly in the model. [40] In so far as the proportion of pregnant brides

is the same both before and after a shift in the age at marriage distribution,

this is unimportant. If the proportion differs then, providing an explicit

quantitative statement can be made, the results in Table 5 can be adjusted.

Experiment 2

Here we report simulations incorporating the "medium" and "high"

schedules of parity specific infant mortality given in Table 1. They are

superimposed on mortality regime level 20. We utilise a comparison between

samples of 100, one from a population where all marry at 23 and one from a

population where all marry at 28.

Table 6.   Results of Experiment 2

All marriages at age	Parity Specific Schedule	Average Births	Average Survivors	Mean Infant Mortality Rates
23	"medium"	7.35	4.23	0.22
28	"medium"	5.51	3.14	0.17
23	"high"	7.84	4.14	0.31
28	"high"	5.45	3.01	0.25

Table 6 shows that if marriage is set back from age 23 to age 28 an average loss of 1.84 births in completed families with the "medium" and 2.29 with the "high" parity specific infant mortality schedule is observed. The loss in terms of survivors, (children still alive when the mother is 45), is reduced to just over one in each case due to the different mean infant mortality rates.

It could be argued a priori that, as an infant death shortens the amenorrhea period and therefore makes the woman susceptible to another pregnancy sooner, the "high" schedule would produce more births than the "medium" but that the difference would be greater the more predominant is the large family, i.e. the lower is age at marriage. Thus the impact of a change in age at marriage, in terms of average births is greater, ceteris paribus, the more significant the parity specific infant mortality. This conjecture is reasonably well supported by the evidence in Table 6. [41]

Experiment 3

The model was simulated for the four distributions of marriage age tabulated in Table 3 using S-C evidence and the "high" schedule for infant mortality rates, together with level 50 and level 20 mortality regimes respectively, for both $\rho = 0$ and $\rho = -1$. The results are given in Table 7 and are again for sample size 100. Average births are given both for completed family size and actual family size, i.e. incorporating premature termination of marriage by adult mortality according to the mortality regime.

The results in Table 7 show that in terms of a shift from K1 to K2 the loss of children in completed families per year's delay of marriage is estimated as .47 ($\rho = 0$, S-C), .40 ($\rho = 0$, "high"), .46 ($\rho = -1$, S-C) and .38 ($\rho = -1$, "high").

Infant mortality rates for the "high" schedule change from 0.35 with K1 to 0.31 with K2 for $\rho = 0$ and from 0.37 to 0.34 for $\rho = -1$, thus confirming the results of analagous trials in Experiment 2.

If the population is viewed as being composed of a proportion λ with $\rho = 0$ and $1 - \lambda$ with $\rho = -1$, the actual value of λ seems unimportant in calculating the impact of a change in marriage age. Even if λ changed from λ_1 to λ_2 with a shift, say, from K1 to K2, then in the S-C case the loss in the average size of completed families per year delay is $.46 - .17\lambda_1 + .18\lambda_2$. Even if λ_1 and λ_2 differ markedly, the conclusion will be little affected.

In the next Section we will consider the implications of our

Table 7.   Results from Experiment 3

Age at marriage distribution	Infant Mortality	Mortality Regime	Average Births (actual)	Average Births (completed)
0 K1	S-C	50	6.72	7.65
0 H1	S-C	50	6.43	6.58
0 H2	S-C	50	5.75	5.87
0 K2	S-C	50	4.66	5.57
0 K1	"high"	20	6.05	7.88
0 H1	"high"	20	5.67	7.07
0 H2	"high"	20	5.25	6.58
0 K2	"high"	20	4.71	6.15
-1 K1	S-C	50	7.02	8.39
-1 H1	S-C	50	6.87	7.38
-1 H2	S-C	50	5.99	7.20
-1 K2	S-C	50	5.60	6.37
-1 K1	"high"	20	6.80	8.66
-1 H1	"high"	20	6.09	7.52
-1 H2	"high"	20	5.85	7.10
-1 K2	"high"	20	4.91	7.01

experiments for assessing the impact of a change in the age at marriage distribution on the population growth rate, taking into account the implications for mortality as well as fertility.

These results indicate that the problem of bias from an association between MCC and age at marriage is likely to be unimportant. Moreover taken by themselves the results from the shift from K1 to K2 might be taken to suggest that in many circumstances the use of inferences from observed statistics of family size of women of a cohort married at different ages may not be a bad estimate of children lost per year's delay of marriage. Reference to the data in Table 4 would yield an estimate of about .44 children foregone per year's delay for this shift, which compares quite closely with the simulation results and certainly does not refute the simulation findings on biases from differential fertility obtaining at different marriage ages.

However, the results also indicate that direct estimation may be quite seriously misleading for a different although similar reason. Corresponding calculations of children foregone per year for the results from a shift from H1 to H2 given in Table 7 show .52 ($\rho = 0$, S-C), .36 ($\rho = 0$, "high", .14 ($\rho = -1$, S-C) and .31 ($\rho = -1$, "high"). Not only are estimates of this statistic gained from a small change in age at marriage likely to have greater variances but also an important point to be grasped is that changes in the distribution of age at marriage about the mean as well as changes in mean age itself can be important in their influence on family size.

Lastly, it seems clear that this evidence gives weight to the order of magnitude of children foregone per year's delay in marriage age proposed by Habakkuk of around 2/5 rather than that suggested by McKeown and Brown of about 1/5.

V

In principle it is possible to extend the model described in Section III to calculate an estimate of the growth rate of population directly by using an initial age distribution, finding birth and death rates of children etc., and eventually a terminal population. Although such a model constitutes an exciting prospect, it also promises to be inordinately expensive in computer time. As we require here only general levels of growth rates and particularly changes in growth rates rather than precise estimates for forecasting etc. we feel justified in limiting our approach to a consideration of common approximations.[42] We use the expressions

$$T \approx \bar{m} - \frac{\sigma^2 \log(GRR)}{2m} \qquad (1)$$

$$r = \frac{\log(NRR)}{T} \qquad (2)$$

where :

r is the growth rate of the population.

T is the approximate length of a generation.

GRR is the gross reproduction rate which we assume to be half the average births per family when considering only completed families multiplied by the proportion of women ever married by age 45, g.

NRR is the net reproduction rate and is equal to $GRR.p(\bar{m})$.

$p(\bar{m})$ is the proportion of females reaching age $\bar{m}$. This will be that given by a standard life table, $1-q(\bar{m})$, minus a premium α depending on the average level of infant mortality, which will in turn depend on the marriage

distribution as was shown in Table 6. Thus $p(\bar{m}) = 1-q(\bar{m}) - \alpha$. $\bar{m}, \sigma^2$ are the mean and variance of the age of a mother at the birth of her live child.

From (1) and (2) it is seen that a change in the distribution of age at marriage represented by a reduction of t years in the mean age at marriage can affect r by the following ways :

(1) $\bar{m}$ will be reduced through marriages having been brought forward. This will imply :

(a) T will be reduced.

(b) $p(\bar{m})$ will be changed: $1-q(\bar{m})$ will be increased, though only slightly as mortality around the age of thirty is low; α may be raised if there is a high schedule of infant mortality which is parity specific

(2) GRR will be increased as long as g does not fall suffic- iently to offset the rise in births per completed family. In general we would expect g to have risen as age at marriage fell in pre-industrial European communities.

In Table 8 the cases where $\rho = 0$ presented in Experiment 3 are analysed to derive values of T and r under the additional assumption that g = .9 and is constant.

Table 8.   Effect of age at marriage on Population Growth rates

At at marriage	Infant Mortality	Mortality Regime	GRR	NRR	T	100r
K1	S-C	50	3.44	2.27	31.7	2.58
H1	S-C	50	2.96	1.96	31.8	2.11
H2	S-C	50	2.64	1.74	31.9	1.74
K2	S-C	50	2.51	1.63	33.7	1.45
K1	"high"	20	3.55	1.46	31.1	1.21
H1	"high"	20	3.18	1.34	31.7	0.91
H2	"high"	20	2.96	1.28	32.1	0.76
K2	"high"	20	2.77	1.22	33.3	0.58

It should be noted that $\bar{m}$ and σ^2 are estimated from simulations yielding actual family size data, whereas GRR is found from completed family size data. α is found from the mean infant mortality rates of the different cases. [43]   All simulations are based on samples of 100.   Approximate generation length, T, at first sight seems rather high but it should be remembered that there is no family planning in the model and that MCC is age specific but not specific to the duration of the marriage. [44]

The percentage rates of population increase given in the last column appear reasonable but attention should be focussed on the way they change with respect to marriage distribution shifts rather than their absolute values.

The results may be considered as follows. First, the absolute change in

100r from a move either from K1 to K2 or from H1 to H2 is larger in

the 50 level case, although the proportionate change is not. Second, the

reduction in growth rate per year reduction in mean age at marriage does not

appear to be large for either marriage distribution, being about .25 at

mortality level 50 and .14 at level 20 for a change from K1 to K2, with

corresponding values of .27 and .11 for H1 to H2.

These results are interesting in the context of the discussion

of the homeostasis hypothesis reported in Section I. [45] They suggest that

in many cases age at marriage would be required to change quite a lot to

influence the rate of population growth enough to offset changes in the economic

or demographic environment, especially in communities with relatively low life

expectancies. For example, starting at mortality level 20 a fall of as little

as five points in the crude death rate might require as much as four years rise

in mean marriage age as a preventive check. On the other hand changes in the

long term rate of growth of incomes were probably not large and nuptiality

might be able to adjust well enough to them to avoid arriving at a subsistence

minimum population in the long run, whilst still being dominated by "fortuitous"

mortality fluctuations in the shorter run.

The requirement of what would apparently be rather large changes

in age at marriage, if this is the primary mechanism of control of fertility,

may both offer support and suggest a reason for Lee's findings reported in

Section I which were that pre-industrial England was characterised by inelast-

icity of fertility with respect to the real wage rate and accordingly a weak

homeostatic mechanism to offset the impact on real wages and population size
of changes in exogenous mortality. However, confirmation of such a hypothesis
for any given society does require information on the magnitude of changes in
marriage age and on the prevailing mortality regime.

This second factor has received little explicit attention in this
context. For instance this may account for Habakkuk's possibly rather large
estimate of 0.3% increase in the population growth rate for a fall of one year
in average marriage age in late eighteenth/early nineteenth century England.
Table 8 suggests that whilst this might be only a little too high at level 50
mortality it would be a gross overestimate at level 20. The main reason for
this, as Tables, 6 7 and 8 imply would not be the parity specific mortality
or low impact on birth propositions advanced by McKeown and Brown - these appear
unimportant and erroneous respectively - or Habakkuk's apparent underestimates
of the length of generation and prior family size. The really important
factor would be that at level 20 high levels of infant mortality, (even if
non parity specific), and child mortality render the impact of change in
marriage age on NRR fairly small.

Armed with these results we can now turn to the controversy
over the role of age at marriage in demographic growth in England between
1700 and 1850. It was to this debate that Habakkuk and McKeown and Brown
were contributing. This dispute has in turn been part of a larger literature
seeking explanations for the increase in the population growth rate from
perhaps zero in the first part of the eighteenth century to about 0.7 -
0.9% per year c.1760 - 1800 and to about 1.2 - 1.4% in the period c.1800 -
1850. [46] Other proponents of the importance of age at marriage include

Connell [47] and Krause [48] whilst other opponents include Razzell [49] and Eversley. [50]

We need to consider both how much age at marriage may have changed and also what level of mortality may have prevailed at various times during this period. Both of these are subject to serious problems of measurement.

Parish register and marriage licence evidence on age at marriage has been marshalled at three levels; at aggregate levels such as by county, at micro levels such as the village and on occasion by occupation. Table 9 summarises a representative sample of this evidence. Knowledge is very imperfect and Table 9 leaves us in some doubt about the probable magnitude of changes in age at marriage.

With regard to life expectancy the first national life table with claims to generality and reasonable accuracy is Farr's table relating to 1838-1854 deaths, i.e. evidence for the era towards the end of our period. This shows life expectancy broadly compatible with level 50. Earlier evidence is available from studies of particular localities based either on parish register or bills of mortality data, on studies of special groups notably the peerage and purchasers of life insurance but not for the general population. The available figures are summarised in Table 10.

The figures presented in Tables 9 and 10 require some discussion. Obviously there must be serious doubts about whether the age at marriage data is typical, particularly the micro data which is generally based on small

Table 9.   Mean Age at First Marriage of Women in England c.1700-1840.

(a) County Data:

	Outhwaite			Razzell	
Suffolk,	1684-1723	24.5	Yorkshire,	1662-1714	23.8
Yorks.,	1691-1710	23.1	Notts.,	1701-1736	24.5
Notts.,	1701-1710	24.2	Surrey,	1741-1745	24.9
Notts.,	1751-1760	24.2	Notts.,	1749-1770	23.9
Suffolk,	1751-1760	25.5	Sussex,	1796-1799	24.1
Surrey,	1751-1760	24.4	England & Wales	1839-1841	24.3
Sussex,	1801-1810	22.3			
Leics.,	1801-1810	23.8			

(b) Micro Data:

Wrigley (Colyton, Devon)		Johnston (Powick, Worcs.)	
1700-19	30.7	born 1663-1700	30.5
1770-99	26.4	born 1751-1775	24.3
1925-37	23.3		

(c) Occupations Data:

Loschky and Krier (18th c. Lancs)		Chambers (18th c. Notts)	
Labourers	22.6	Gentlemen	21
Craftsmen	25.0	Labourers	24
Farmers	27.3	Yeoman	22

Notes to Table 9 : Sources of data :

R.B. Outhwaite, "Age at Marriage in England from the late Seventeenth to the Nineteenth Century," Transactions of the Royal Historical Society 5th. series 23 (1973) p.61.

P.E. Razzell, op.cit., p.132.

E.A. Wrigley, op.cit., p.87.

J. Johnston,"Family Reconstitution and the Local Historian," Local Historian 9 (1970) p.11.

D.J. Loschky and D.F. Krier, "Income and Family Size in Three Eighteenth Century Lancashire Parishes : A Reconstitution Study, "Journal of Economic History 29 (1969) p.435.

J.D. Chambers, "The Course of Population Change", excerpt from "The Vale of Trent 1670-1800 : A Regional Study of Economic Change", Supplement 3 to the Economic History Review (1957), reprinted in D.V. Glass and D.E.C. Eversley, op.cit., p.332.

Chambers' figures are medians not means.

samples and may reflect local peculiarities even if the sample means do

accurately measure the population means.

        There is a further reason for caution before generalising the

age at marriage experience of particular villages to the national level.

Village level studies always seem to exhibit more variation in marriage age

over time than do county level data.   Still less volatility in age at marriage

emerges from a comparison of averages of the county figures for different

periods.   However, it might be expected that over a period of given length a

Table 10.   Evidence on English Life Expectancy c.1700-1850.

Date	Coverage	Approximate Life Table (U.N.)
1762-1829	Equitable Life Assurance Deaths	Level 50
born 1700-1724	Peerage	Level 30
born 1750-1774	Peerage	Level 50
born 1800-1824	Peerage	Level 60
1625-1699.	Colyton Adult Deaths	Level 25
1700-1774	Colyton Adult Deaths	Level 40
c.1750-1770	Average of Shrewsbury, Northampton and Chester bills of mortality	Level 20
1779-1787	Carlisle bills of mortality	Level 55
c.1730-1780	London bills of mortality	Level 5

Notes to Table 10 : Sources of Data :

Lines 1 and 7-9 from W.P. Elderton and M.E.Ogborn, "Mortality of Adult Males since the Middle of the Eighteenth Century as shown by the Experience of Assurance Companies, "Journal of the Royal Statistical Society 106 (1943) pp. 18-19.

Lines 2-4 from T.H. Hollingsworth, op.cit., pp.56-57

Lines 5-6 from E.A. Wrigley, "Mortality in Pre-Industrial England : the Example of Colyton, Devon over three Centuries, "Daedalus 97 (1968) p.573

small village in this era would have more fluctuations in mean marriage age

than the country as a whole.

If villages are characterised by a substantial degree of
endogamy but have small absolute size of marriage market it seems
intuitively that problems of incompatibility of potential spouses within
the same age group, e.g. simply from inbalance of the sexes, will occur.
This may be reflected in marriages of unusually large gaps in age between
partners and an inverse movement in first marriage ages of men and women,
as occurred to some extent in Colyton. [51] Over a large number of villages,
(a county for example), such random short term fluctuations would tend to
cancel out.

For these reasons, in talking about long term changes in demographic
regime at a national level, which has been the focus of the debate, it seems to
us unsafe to rely on inferences from the village figures. The county figures
are based on much larger samples drawn from much wider areas but they too are
not without problems. In particular, they probably would not adequately
capture the effects of structural changes associated with industrialisation,
(enclosure, urbanisation etc.,) on the marriage market. The fragmentary
occupations data is still more unsatisfactory being based on a period before
the putatively important changes in social structure became widespread.

It is difficult, therefore, to draw any firm conclusions about the
extent of changes in age at marriage in England between 1700 and 1850. How-
ever in the light of Table 8 it does seem potentially very important whether
the village evidence is preferred to the county figures. With the former one

might think in terms of a fall of at least five years in age at marriage
over the period.   With the latter three years would be the extreme upper
bound or using averages of county figures perhaps a change of one and a half
years downwards subsequently largely reversed.

    The evidence of Table 10 on life expectancy also presents a some-
what confused picture.   A general tendency in the literature has been to treat
the peerage as a privileged group who would have a life expectancy greater
than that of the population as a whole. [52]   If that were the case then in
concert with the urban bills of mortality, (London being by common consent
typically unhealthy), this would suggest that at least up until the mid-
eighteenth century mortality conditions were close to the level 20 used in
some of our simulations as far as the national average is concerned. By the
end of our period when we have national figures of a reliable kind indicating
level 50, the other level used in our simulations would be applicable.   The
pattern of improvement in between would be uncertain but again by arguing that
the peerage life expectancy leads the general average somewhat it might be
guessed that a level of 35 or 40 applied c. 1800 (the towns and country areas
differing considerably).

    The Colyton and Carlisle figures do not fit this picture.   If they
were accurate and typical, both the view that the peerage had a higher life
expectancy in the eighteeenth century and the idea that level 20 might be
applicable to say, 1750, would be erroneous.   It is certainly plausible that
rural areas were a bit healthier than the towns from which the bills of

mortality come. It is perhaps difficult to believe that mortality conditions quite as good as those reported for Colyton prevailed generally in England between, say, 1700 and 1750, unless it is believed birth control was of some importance, for with prevailing age at marriage, even at Colyton's maximum the simulations in Table 8 indicate population growth would otherwise have been distinctly above zero in this period. [53] Also it is difficult to believe that the peerage had a worse life expectancy than average. Level 30 may then be a reasonable upper bound for the early part of our period, but the existence of some doubt must be acknowledged.

Table 8 presented estimates of the extent of the change in age at marriage required to effect a given change in population growth rate at different levels of life expectancy and the evidence of Tables 9 and 10 can now be discussed in that context. We have no particular reason to suppose that the estimates in Table 8 are invalidated by large changes in g or unusual marriage distributions in this historical situation. In the light of Tables 5 and 7 the likely rise in pre-marital pregnancy does not seem to vitiate use of these results.

A wide range of views about age at marriage is left open by our results. If it was deemed acceptable to generalise from the Colyton type evidence then potentially it would seem that age at marriage could "account" for practically the whole of the observed rise in population growth rate. On the other hand reliance on county data for marriage age and putting mortality at level 30 or less in 1750, level 40 or so in 1800 would give a maximum impact of about 0.2% on the population growth rate in the second half of the eighteenth and 0.3% in the early nineteenth, with a considerable likelihood that in fact the impact was negligible. It should be noted that these would be

overestimates of the impact of age at marriage changes to the extent that

falls in marriage age were associated with moves of population to less healthy

urban areas or produced induced effects tending to raise mortality.

Obviously the need now is for better quality information on both

marriage ages and life expectancy. We can offer only tentative opinions as to

the likely state of events. We have reasons above for regarding the county

evidence as the more reliable information about marriage ages and for supposing

that the level of mortality was not better than level 30 before 1750, and hence

was not in the range where falls in age at first marriage could be relatively

powerful. If these suppositions turned out to be correct then it would appear

that age at marriage must have played at best a supporting role in stimulating

population growth, both in the sense of the magnitude of its impact on the

grounds that it did not change much and in the sense that it would be much more

potent later in the period after a preceeding fall in mortality. On both

these counts the position of McKeown and Brown would be correct. However,

Habakkuk's hypothesis that a fall in age at first marriage could account for

the observed increase of about 0.5% in the population growth rate in the first

half of the nineteenth century would remain a very live possibility. [54]

It seems unlikely to us that age at marriage changes should get

credit for more than a supporting role in the English demographic revolution

in an accounting sense. This would not, however, necessarily mean that the

homeostasis hypothesis was unimportant in its implications for these events.

As Marshall observed more than fifty years ago it is most interesting that when

the crude death rate appears to fall in the late eighteenth century the crude

bith rate apparently remained at a high level. [55] What this may mean from

the perspective of the homeostasis notion is that a new equilibrium was chosen rather than moves to restore the old one being invoked. It might be reasonable to suppose that in the late eighteenth century a rise of say three years in mean age at marriage could have at least halved the population growth rate. If, as it would seem, this did not occur, that may be the interesting thing to attempt to explain.

VI

Our findings can be summarised in terms of three main propositions.

(1)   It seems likely that in most cases children foregone

per year's delay in mean age at marriage will be around

the amount suggested by Habakkuk of 2/5.   This may vary

though if the shape of marriage distribution is unusual.

In terms of population growth this will mean an increase

of a little over 0.1% at level 20, a little over 0.25%

at level 50 mortality.

(2)   This provides good reason for the weak homestasis finding

of Lee for the pre-industrial English case and suggests

that in non-contracepting populations there will only be

a high elasticity of fertility with respect to the real

wage rate if the social structure is such as to induce

large changes in age at marriage in response to a change

in real wage rate.

(3)   Age at marriage probably played no more than a supporting

and secondary role in the English demographic revolution.

This conclusion would not hold if Colyton's experience

were typical of all England.   Better evidence on marriage

ages and mortality regimes are highly desirable.

FOOTNOTES

1. Useful collections of readings from the controversy can be found in D.V. Glass and D.E.C. Eversley (eds.), _Population in History_ (London, 1965) and M. Drake (ed.), _Population in Industrialisation_ (London, 1969).

2. H.J. Habbakkuk, _Population Growth and Economic Development since 1750_ (Leicester, 1971) p.8.

3. J.D. Chambers, _Population, Economy and Society in Pre-Industrial England_ (Oxford, 1972) pp. 15-16.

4. J.Hajnal, "European Marriage Patterns in Perspective", in D.V. Glass and D.E.C. Eversley, _op.cit._, pp. 101-147.

5. E.A. Wrigley, "Family Limitation in Pre-Industrial England", _Economic History Review_ 19 (1966), pp. 104-107.

6. H.J. Habakkuk, _op.cit._, p. 20.

7. The differences between those who prefer Habakkuk's view of the world and those who prefer Chamber's is one of emphasis; Chambers also recognises the likely importance of age at marriage in population change but stresses stochastic events much more than does Habakkuk.

8. T. McKeown, R.G. Brown and R.G. Record, "An Interpretation of the Modern Rise of Population in Europe", _Population Studies_ 26 (1972) pp. 355-356.

9. R. Lee, "Population in Pre-Industrial England : An Econometric Analysis", _Quarterly Journal of Economics_ 87 (1973), p. 593.

10. _Ibid._, p. 605.

11. N.F.R.Crafts and N.J. Ireland, "An Analysis of Parish Register Evidence of Family Limitation : An Example of the Use of Simulation Techniques in Economic History", paper presented to the European Meeting of the Econometric Society, Grenoble, September 1974.

12. D.E.C. Eversley, "Population, Economy and Society", in
    D.V. Glass and D.E.C. Eversley, op.cit., p.45.

13. E.A. Wrigley, op.cit., p.88.

14. T. McKeown and R.G. Brown, "Medical Evidence related to English
    Population Changes in the Eighteenth Century", Population
    Studies 9 (1955), reprinted in D.V. Glass and D.E.C. Eversley,
    op.cit. pp. 286-307, and M. Drake, op.cit., pp. 40-72.   It
    should be noted that this implies a difference from the model
    of figure 1 in that movements along the fertility schedule
    will not under this argument be independent of shifts in
    mortality regime.

15. H.J. Habakkuk, op.cit., p.38.

16. T. McKeown and R.G. Brown, op.cit., p.58.

17. J.C. Dunlop, "The Fertility of Marriage in Scotland : a Census
    Study", Journal of the Royal Statistical Society 77 (1914),
    pp. 259-288.

18. For a detailed discussion of the definition and measurement of
    MCC see N.F.R. Crafts and N.J. Ireland, "The Role of Simulation
    Techniques in the Theory and Observation of Family Formation",
    Population Studies 29 (1975) pp. 75-95.

19. P.E.H. Hair, "Bridal Pregnancy in Rural England Further Examined",
    Population Studies 24 (1970), pp. 59-70.

20. R.E. Kennedy jr., The Irish : Emigration, Marriage and Fertility
    (Berkeley, 1973).

21. D.E.C. Eversley, op.cit., p.40.

22. D. Scott-Smith, "A Homeostatic Demographic Regime : Patterns in
    West European Family Reconstitution Studies", paper presented to
    N.S.F./M.S.S.B. Conference on "Behavioural Models in Historial
    Demography", University of Pennsylvania, October, 1974, p.15.

23. Ibid., p. 18.

24. Habakkuk at least recognises this;   see his comments reported in
    F. Bechofer (ed.,) Population Growth and the Brain Drain
    (Edinburgh, 1969) p. 226.

25. The plausibility of these assumptions is discussed below and in
    N.F.R. Crafts and N.J. Ireland, op.cit., (fn. 18).

26.   For a definition see below p. 30.

27.   N.F.R. Crafts and N.J. Ireland, op.cit., (fn. 11), pp. 4-5 and
        op.cit., (fn. 18), pp. 79-80.

28.   N.F.R. Crafts and N.J. Ireland, op.cit., (fn.18).

29.   J.E. Cohen, "Childhood Mortality, Family Size and Birth Order in
        Pre-Industrial Europe", Demography 12 (1975) pp. 35-55.

30.   J. Stoeckel and A.K.M. Alauddin Chowdhury, "Neo-Natal and Post-Neo-
        Natal Mortality in a Rural Area of Bangaladesh, "Population Studies
        26 (1972), p. 119.

31.   J.R. Gibson and T. McKeown, "Observations on all Births (23,970)
        in Birmingham, 1947, VII, Effect of Changing Family Size on Infant
        Mortality" , British Journal of Social Medicine 6 (1952) p. 185.

32.   Although previous writers have generally confined themselves to
        discussions of changes in marriage age mean, the results below in
        Table 7 indicate this may be an unwise oversimplification; changes
        in the distribution about the mean are likely to matter also as far
        as changes in family size are concerned.

33.   D.V. Glass, "Introduction", in D.V. Glass and D.E.C. Eversley (eds.),
        op.cit.

34.   T.H. Hollingsworth, "Demography of the British Peerage", Population
        Studies (Supplement) 17 (1964) p. 17; (data adjusted to eliminate
        celibacy).

35.   A.J. Coale, "Age Patterns of Marriage", Population Studies 25
        (1971), pp. 193-214.

36.   See N.F.R. Crafts and N.J. Ireland, op.cit., (fn. 11), and the caveats
        made there.

37.   D. Scott-Smith, op.cit., data in Table 1 p. 16.   The studies in the
        sample were chosen to cover only those parishes in which there was
        thought to be no sign of the use of contraceptive techniques.   It
        should be noted that when the results of these simulations were
        compared with Hollingsworth's actual data they conformed less closely
        to the observed statistics the more time had elapsed since marriage
        for the groups married both between 15-25 years and 25-35 years of age.
        This tends to confirm Hollingsworth's inference that birth control was
        being used by the peerage from an early date.   See T.H. Hollingsworth,
        op.cit., Table 28 and p. 51.

38. As Scott-Smith notes, op.cit., page 12, despite his efforts to concentrate on cases of natural fertility there are signs that his sample contains a significant amount of conscious control over fertility at higher ages. Therefore the excess of simulated over actual fertility at periods of more than 15 years in Table 4 may not be at all surprising. The difficulty of inference from observed statistics to obtain the "pure" impact of marriage age changes is emphasised by this.

39. McKeown and Brown, op.cit., might be thought to argue that case (a) is unbiased whereas something like case (b) is often intuitively imagined through comparison of women who marry at the same age but have their first child at different ages. An analagous problem exists if it is thought that observed statistics are drawn from a population with a high degree of association between age at marriage and MCC; in that case the temptation would be to accept the observed values of type (b) which would be over-estimates since the (unobserved) values of type (c) would be the unbiased information. Here we are arguing that the bias from observing (b) rather than (c) is not likely to be large.

40. We tried a variant of our model where all women had pre-marital intercourse and married according to a given age at marriage (if not pregnant) distribution or when they became pregnant, whichever came first. As noted previously, this approach required arbitrary assumptions concerning the age at pre-marital intercourse distribution, the age at marriage (if not pregnant) distribution, the relationship between them and the chance of conception during the pre-marital period in relation to the marital period. We found that the rank correlation between observed age at marriage and MCC varied between 0.2 and 0.3. A shift in the observed age at marriage distribution could of course result from either a change in the age at marriage (if not pregnant) distribution or a change in the parameters governing the pre-marital intercourse experience of women. Difficulties such as this persuaded us to consider the simplified model of the MCC age at marriage relationship described in Experiment 1.

41. The same conjecture is not supported by the evidence from Experiment 3. Reasons may include the shapes of the various age at marriage distributions and larger sampling variations due to differing ages at marriage.

42. See, for instance, R. Lesthaeghe, "Nuptuality and Population Growth", Population Studies 25 (1971), pp. 415-432.

43.   Typical differences in infant mortality rates for the different cases continued to be $\Delta/100$, where Δ is the difference in mean age at marriage.

44.   Habbakkuk's estimate of 25 years, op.cit., p. 38, seems to be too low for the type of community being considered and biases upward his calculation of the growth effects of marriage age change.

45.   It should be noted that these results could be subject to changes if there was a large change in g associated with the change in age at marriage or if the distribution of marriage ages about the mean altered in a pronounced way. The model is of course perfectly capable of handling either case if evidence from a given community requires it to do so.

46.   For a convenient review of the debate and further references see M.W. Flinn, British Population Growth 1700-1850 (London 1970).

47.   K.H. Connell, "Some Unsettled Problems in English and Irish Population History", Irish Historical Studies 7 (1951) reprinted in M. Drake, op.cit.

48.   J.T. Krause, "Some Neglected Factors in the English Industrial Revolution", Journal of Economic History 19 (1959) reprinted in M. Drake, op.cit.

49.   P.E. Razzell, "Population Change in Eighteenth Century England : a re-appraisal", Economic History Review 2nd. ser. 18 (1965) reprinted in M. Drake, op.cit.

50.   D.E.C. Eversley, op.cit.

51.   Demonstration of this proposition for any acceptably realistic model would seem to require a full scale simulation of a stochastic marriage. market. If the supposition in the text did turn out to be correct, however, then it is worth noting that in Colyton the highest age at first marriage for women when age at marriage for men was as "normal" higher was only 27.7 as opposed to the 30.7 high of Table 9. Perhaps the Colyton evidence indicates a long run, (trend) decline in female marriage age of, say 4.5 rather than 7.5 years.

52.   See for example, D.V. Glass, op.cit.

53.   It should be noted that 1700-1750 may represent a short run, "fortuitous" aberration in English demographic history. As Tucker has noted neither the "normal" tendency of the pre-industrial demographic regime nor the origin of a new trend rate of growth has been precisely established; G.S.L. Tucker, "English Pre-Industrial Population Trends", Economic History Review 2nd ser. 16 (1963) pp. 205-218.

54.   H.J. Habakkuk, op.cit., pp. 38-39.

55.   T.H. Marshall, "The Population Problem during the Industrial
       Revolution : A Note on the Present State of the Controversy",
       Economic History 1 (1929), reprinted in D.V. Glass and D.E. Eversley,
       op.cit., pp. 247-268. The figures of crude birth and death rates
       on which his remarks were based are subject to severe criticisms;
       for a short summary of some of the most serious problems see
       N.F.R. Crafts, "Local Population Studies in the Context of Aggregate
       Estimates for the Eighteenth Century", Local Population Studies 13
       (1974) pp. 19-31.