UNIVERSITY OF OXFORD

Discussion Papers in Economic and Social History

Number 99, May 2012

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16 May 2012

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Abstract

This paper uses demographic data drawn from Wrigley *et al.*'s (1997) family reconstitutions of 26 English parishes to adjust Allen's (2001) real wages to the changing demography of early modern England. Using parity progression ratios (a fertility measure) and age specific mortality for children and parents, model families are predicted in two reference periods 1650-1700 and 1750-1800. These models yield two levels of interesting results. At the individual family level, we can measure how different families' real wages changed over the family life cycle as additional children were born. At the aggregate level, we can predict thousands of families using Monte Carlo simulation, creating a realistic distribution of median family real wages in the economy. There are two main findings. First, pregnancy and lactation do not create cyclical effects in the family's income. Instead, most families' welfare ratios decline steadily across the family life cycle until children begin to leave the household, increasing the welfare ratios. Second, Allen's real wages understate or match the median of the predicted demography-adjusted distributions.

[1] The author wishes to thank Deborah Oxley and Bob Allen for helpful comments as well as participants in the Household Decision Making in History Workshop at All Souls College, Oxford and seminar participants at Lund University and the HPSS group at the University of Cambridge. The usual disclaimer applies.

Introduction

The flurry of scholarship in the last decade reconstructing historical real wages around the world has fundamentally changed the way economic historians understand the Great Divergence debate. By comparing nearly identical consumer price baskets and labourers' wages, first Allen and then his collaborators were able to construct comparable real wages for most parts of the world including North America, Latin America, Europe, Africa, India, and China.[2] These papers have generally refuted the California school position that parts of China and India were just as developed as Europe in the eighteenth century. Real wages were quite low around the world from the sixteenth century onwards with notable exceptions in Britain and the Netherlands.

This scholarship has been tremendously helpful in reconstructing the economic history of the world, but in order to make international comparisons, Allen and his co-authors made certain assumptions about family size and composition over time and across countries. Allen based his family size assumptions on an English gardener from Ealing, who had a wife and four small children, described by Sir Frederick Eden in *The State of the Poor* in the 1790s. Therefore, Allen assumed that the average family size and composition around the world was similar and consisted of the equivalent energy needs of three adult males.[3] Humphries has recently criticized Allen's constant family size as being too low for England, thus making his English real wage estimates too high. There is therefore room in the literature for a careful reworking of the relationship between family size and real wages.

In general Allen's family size assumption may be justifiable because of the paucity of detailed demographic information that would allow historians to precisely vary family size over time for many countries. Family size is also difficult to proxy with other demographic variables because it depends not only on fertility measures but also on the mortality of children. However, there is good demographic data for England from which we can attempt to understand how changing family size influenced real wages over time. This paper will use demographic data drawn from Wrigley *et al.*'s family reconstitutions of 26 English parishes to adjust Allen's real wages to the changing demography of early modern England.[4] Using parity progression ratios (a fertility measure explained later) and age specific mortality for children and parents, model families are predicted for two reference periods, 1650-1700 and 1750-1800. We can then study how the changing size and composition of an individual family affected its 'welfare ratio'[5] over the family life cycle. The welfare ratio is the wage earned by the father divided by the consumption requirements of the family in any given year. In addition, Monte Carlo simulation can be employed to predict thousands of families in each reference period, providing a realistic distribution of welfare ratios based on the different families possible. These distributions can then be compared with Allen's original figures to measure the influence of changing family size and structure on real wages.

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[2] Allen, 'Great Divergence'; Allen, *et al*., 'Wages'; Allen, *et al*., 'Colonial'.

[3] Allen, *British Industrial Revolution*, p. 29.

[4] Wrigley, *et al.*, *English Population History*.

[5] Throughout the paper, real wage will be used to refer to inflation adjusted male wages. Welfare ratio will be used to denote the family size and inflation adjusted male wage, i.e. the purchasing power of a family with certain demographic characteristics.

Previous Attempts

There have been two previous attempts to account for family size in real wage calculations. First, in their paper on real wages and the industrious revolution, Allen and Weisdorf attempted to account for fluctuations in family size by using the net reproduction rate and the dependency ratio of the population to recalculate the size of the household in different years. The net reproduction rate is the average number of daughters surviving to reproductive age that would be born to a female if she conformed to the age-specific fertility and mortality rates throughout her lifetime. The dependency ratio is the number of people aged 15 and under and aged 60 and older divided by the people in the population aged 16-59. To calculate family size from these proxies, Allen and Weisdorf held that family size would be equal to two adults plus the net reproductive rate, and they used the dependency ratio as an index to calculate family size.[6]

Allen and Weisdorf's use of these proxies was a good first attempt to understand the effect of changing family size on household consumption requirements, but it is insufficient for several reasons. First, they did not adjust the net reproduction rate to account for males that might have been born in the household. Two adults plus the net reproduction rate would be the father, mother, and the daughters born to the household but would not include sons. Therefore, a better measure might have been two plus the net reproduction rate times two, assuming that the same number of sons and daughters were born. They also do not allow children at different ages to influence the family's consumption differently. Teens needed many more calories than new-borns, and counting them the same clearly would influence their results. In addition, the dependency ratio is not a very good proxy because it is a measure of the cost of those not of working age on those of working age; it thus spreads the burden of those not working across the entire population instead of measuring the burden of dependents on families in society. These problems clearly limit the usefulness of the adjustment in the Allen-Weisdorf paper.

Jane Humphries has also attempted to account for changing family sizes on real wages in her paper criticizing Allen's method. She argued that the Ealing gardener's family was not representative of the English population, where larger family sizes were more common. To support this argument, she presented completed family size and sibling group size figures computed from the Cambridge group reconstitutions, which were much larger than Allen's model family.[7] However, these figures are also problematic. In the context of the Wrigley *et al.* family reconstitutions, a completed family is one where the mother survived to age 50. Thus, using these figures alone would overestimate family size since many women died before the age of 50. Likewise, with high infant and childhood mortality rates, many children would have died before adding substantially to the household's consumption requirements. Finally, although women may have had many children, it is doubtful that all of them were a burden on the household at the same time because birth spacing was quite wide. Clearly, previous attempts to understand how family size influenced real wages have provided an interesting starting point for discussion, but a more complex method that incorporates both fertility and mortality is necessary to truly understand what the influence might be.

[6] Allen and Weisdorf, 'Industrious Revolution', pp. 723-26.
[7] Humphries, 'Lure', pp. 18.

Real Wages, Consumption, and Family Income

Before describing the predictive model in detail, it is first necessary to describe how family consumption and the family's welfare ratio over the family life cycle has been calculated in this paper. The family's consumption was determined by the number of people needing to be fed, clothed and housed and by the additional consumption requirements of pregnancy and lactation. In order to measure this level of consumption uniformly, it was necessary to convert the consumption of children and adults of both sexes and at different ages into consuming units, the equivalent consumption of an adult male.[8] Fortunately, the Food and Agriculture Organization (FAO) has published recommended guidelines of caloric consumption for male and female children and adults, which allow these conversions to be calculated.

Table 1: Energy requirements of male and female children.

	Males				Females			
Age (years)	Total Energy Expenditure (kcal/day)	Energy Deposited for Growth (kcal/day)	Daily Energy Requirement (kcal/day)	Consuming Unit Equivalent	Total Energy Expenditure (kcal/day)	Energy Deposited for Growth (kcal/day)	Daily Energy Requirement (kcal/day)	Consuming Unit Equivalent
			(1) + (2)	(3) / 2900			(5) + (6)	(7) / 2900
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1-2	934	14	948	0.3269	851	14	865	0.2983
2-3	1,117	11	1,129	0.3893	1,035	12	1,047	0.3610
3-4	1,240	12	1,252	0.4317	1,145	11	1,156	0.3986
4-5	1,349	11	1,360	0.4690	1,231	10	1,241	0.4279
5-6	1,456	11	1,467	0.5059	1,320	10	1,330	0.4586
6-7	1,561	12	1,573	0.5424	1,415	13	1,428	0.4924
7-8	1,679	14	1,692	0.5834	1,537	17	1,554	0.5359
8-9	1,814	16	1,830	0.6310	1,678	21	1,698	0.5855
9-10	1,959	19	1,978	0.6821	1,831	23	1,854	0.6393
10-11	2,128	22	2,150	0.7414	1,981	25	2,006	0.6917
11-12	2,316	25	2,341	0.8072	2,123	25	2,149	0.7410
12-13	2,519	29	2,548	0.8786	2,250	26	2,276	0.7848
13-14	2,737	33	2,770	0.9552	2,355	24	2,379	0.8203
14-15	2,957	33	2,990	1.0310	2,430	19	2,449	0.8445
15-16	3,148	30	3,178	1.0959	2,478	12	2,491	0.8590
16-17	3,299	24	3,322	1.1455	2,499	5	2,503	0.8631
17-18	3,396	15	3,410	1.1759	2,503	0	2,503	0.8631

Notes: The baseline consuming unit energy requirement was held to be 2900 kcal/day, which was the recommended energy requirement for an adult male aged 18-29.9 with a BMI of 21 and a PAL of 1.75. Sometimes columns do not add precisely because of rounding in the original FAO report.

Sources: FAO, 'Human', pp. 26-27.

I have followed Floud *et al.*'s conventions for converting older men and adult women to consuming units.[9] However, Floud *et al.*'s categorization of children into five-year age groups is too broad to usefully capture the increasing burden of a child on a family as it grows. Therefore, I have used the FAO recommended calorie requirements of male and female children and adolescents, provided in Table 1 above. These energy requirements are based on the average weight of children at each age and on their estimated PAL given the typical activity level and the rate of growth at each age. These figures have been updated between the 1985 FAO report that Floud, *et al.* used and the 2004 FAO report, so it is worth reporting them here.[10] The calorie

[8] Allen, 'Great Divergence'; Floud, *et al.*, *Changing Body*, pp. 43-6.
[9] Floud, *et al.*, *Changing Body*, pp. 46, 166.
[10] FAO, 'Human', pp. 26-7.

requirements of children at each age were divided by the 2900 calories required by an adult male aged 18-29.9 to produce the relevant consuming unit equivalent.[11] These calorie requirements are based on modern populations with modern body sizes, which were different than those in the past. However, the calorie requirements of men relative to women and children were likely similar if not identical in the past, and there is little evidence from before the nineteenth century upon which to base historical estimates anyway, especially for female adult heights and weights and children's growth.

In determining the costs of lactation and pregnancy, I have followed Humphries and the FAO guidelines.[12] Being pregnant raises a woman's daily energy requirements differently in each trimester of pregnancy: 85 kcal in the first, 285 kcal in the second, and 475 kcal in the third.[13] This averages to 282 additional kcal/day throughout the pregnancy and 211.25 kcal/day on an annual basis. A woman needs an additional 675 kcal/day in the first six months of breast-feeding and 460 kcal/day after the first six months until weaning, which is assumed to take place at 18 months.[14]

Using the calorie requirements for adults and children at various ages and for pregnancy and lactation, it is possible to precisely calculate a family's consumption needs throughout the family life cycle. This method provides a more dynamic picture of household consumption than Allen's original construction of real wages, where he assumed a constant family size.

Both of Allen's consumer price baskets, the subsistence and respectability baskets, will be employed in this paper (Table 2). The subsistence basket was designed as a theoretical basket of goods with only enough food and non-food items for survival (1,938 calories per consuming unit). Thus, if a family could only afford to buy the subsistence basket – a subsistence welfare ratio of one – they had enough food to survive in the short term. It should be noted that Allen's subsistence basket truly marks the subsistence level. It would be very difficult for an active adult male to survive on less than 1,938 calories per day. The respectability basket, on the other hand, was based on the Eden household budgets providing a higher level of calories and protein and a more historically representative basket of goods. Allen used it to demarcate a respectable living standard with nice foods such as bread, beer, cheese and eggs, which British people and especially Londoners had come to expect by the end of the eighteenth century. If a family could purchase the respectability basket – a respectability welfare ratio of one – then they could afford to feed everyone in the family 2500 calories per consuming unit of this fancier food.

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[11] FAO, 'Human', p. 41.
[12] Humphries, 'Lure', p. 13.
[13] FAO, 'Human', p. 59.
[14] FAO, 'Human', p. 65.

Table 2: Allen's Respectability and Subsistence Basket of Goods

	Panel A: Respectability Basket of Goods			Panel B: Subsistence Basket of Goods		
	Quantity per Consuming Unit per Year	Nutrients per Day		Quantity per Consuming Unit per Year	Nutrients per Day	
Good		Calories	Grams of Protein		Calories	Grams of Protein
Bread	234 kg	1,571	64	—	—	—
Oatmeal	—	—	—	155 kg	1,657	72
Beans/peas	52 L	370	28	20 kg	187	14
Meat	26 kg	178	14	5 kg	34	3
Butter	5.2 kg	104	0	3 kg	60	0
Cheese	5.2 kg	54	3	—	—	—
Eggs	52 each	11	1	—	—	—
Beer	182 L	212	2	—	—	—
Soap	2.6 kg	—	—	1.3 kg	—	—
Linen	5 m	—	—	3 m	—	—
Candles	2.6 kg	—	—	1.3 kg	—	—
Lamp oil	2.6 L	—	—	1.3 L	—	—
Fuel	5.0 M BTU	—	—	2.0 M BTU	—	—
Rent	5% allowance	—	—	5% allowance	—	—
Total		2,500	112		1,938	89

Sources: Allen, *British Industrial Revolution*, pp. 36-7.

Allen's building labourer and agricultural labour wage series for southern England will be used to calculate welfare ratios in the simulations.[15] These two wage series best reflect the demographic information available in the family reconstitution parishes, which were made up of rural and small town parishes and did not include any parishes from London. They also reflect two large groups of the labouring poor whose wages followed different trajectories across the early modern period: building labourers' real wages improved whereas agricultural labourers' real wages stagnated or decreased. Because the focus of this study is the role of changes in family size and age structure on the family's welfare ratio, prices and wages were held constant at fifty-year average levels. The fifty-year average nominal prices and wages as well as welfare ratios are reported in table 3.

In order to calculate the family's welfare ratio, I assumed, following Allen, that the family's income came only from the day wages of the father, a building or agricultural labourer who worked 250 days per year. This income was divided by the cost of buying either the subsistence or respectability basket for a family based on the consumption requirements of the household (family size). The additional food costs required for pregnancy and lactation were priced in terms of the food component of the basket rather than the entire basket. Thus, it was possible to calculate the welfare ratio of a family in every year of the family life cycle as additional children were born, parents and children died, and children left the household.

[15] Allen, 'London', spreadsheet.

Table 3: Allen's nominal prices, wages and welfare ratios.

	Respectability Basket		Subsistence Basket	
	1650-1700	1750-1800	1650-1700	1750-1800
Food Cost of the Basket per Day (1 consuming unit)	1.59	1.89	0.46	0.58
Non-Food Cost of the Basket per Day (1 consuming unit)	0.25	0.29	0.14	0.16
Total Cost of the Basket per Day (1 consuming unit)	1.84	2.19	0.60	0.74
Southern England Agricultural Labourer's Day Wage	5.57	5.89	5.57	5.89
Southern England Building Labourer's Day Wage	5.63	8.36	5.63	8.36
Allen Agricultural Labourer's Welfare Ratio	0.66	0.59	2.02	1.73
Allen Building Labourer's Welfare Ratio	0.67	0.83	2.04	2.45

Notes: Prices and wages listed in grams of silver. See text for welfare ratio calculation method.

Sources: Allen, 'London', spreadsheet.

The Model

Models of all types are simplifications of a complex reality. This one is no different, so it is important to begin the discussion of the model by highlighting some key simplifying assumptions necessary to produce the model. First, welfare ratios, as Allen designed them, were meant to capture the living standards of families, and therefore, welfare ratios are only calculated for families with children and at least one parent living. The family life cycle begins when a woman becomes pregnant and ends when the final child leaves the household. Thus, unmarried individuals, childless married couples, married couples whose children have left the household or died, and orphans (children who had lost both parents) are not included in the model. Second, all families start out with a married couple removing illegitimacy from the model. The fertility measures in Wrigley *et al.* pertain only to legitimate fertility, so it is better to limit the model in this way. Illegitimacy was relatively rare in the reference periods used in this paper, and the mortality rates of illegitimate children were substantially higher than those for legitimate children, making the addition of illegitimate births particularly difficult to add into the model. Third, no remarriage is allowed. Historical information about remarriage is highly problematic and does not allow for the systematic incorporation of remarriage into the model. Thus, if one parent died, the family was forced to live on the other parent's income for the rest of the family life cycle. Fourth, resources are allocated equally in the household based on the calorie consumption requirements for individuals of each sex at specific ages. This includes giving women more calories when they are pregnant or lactating. This assumption is problematic because it is unclear whether calories were actually allocated within the household in this way. The male breadwinner could have taken more of the family resources for himself, leaving the rest of the members of the family with less.[16] Finally, average English demography is applied to the families of labourers that are targeted by Allen's real wages. Class targeted demographic figures do not exist for the early modern period, so this is an unfortunate but necessary assumption.

Having discussed how a family's welfare ratio is calculated and highlighted some key assumptions of the model, it is now possible to describe the model used to

[16] Horrell, *et al.*, 'Measuring Misery', p. 95.

predict families. The model can be broken into three main elements, fertility, mortality, and children leaving the household, which all strongly influenced family size. The model will be predicted for two reference periods: 1650-1700 and 1750-1800. Unfortunately the published demographic figures in Wrigley *et al.* do not allow for a more granular analysis at this point.

To begin with fertility, if a couple is married, it is possible to use parity progression ratios (PPRs) to predict whether children are born in a family. PPRs are simply the percentage of women who have *another* child after giving birth to *n* number of children (*n* becoming the 'parity'). For example, the PPR at parity one is the percentage of women who have a second child after their first child is born; the PPR at parity two is the percentage of women who go on to have a third child; and so on. PPRs are always less than unity because a certain percentage of the population is or becomes sterile. Thus, PPRs normally decrease with each additional child born and as the woman becomes older. Wrigley *et al.* provide non-age specific PPRs from bachelor/spinster completed marriages for hundred-year periods across early modern England.[17] PPRs from completed marriages were employed because they establish a baseline level of fertility for women who did not die prematurely, though the women will be given a probability of premature death below. Thus, the PPRs from 1650-1749 and from 1750-1837 were used to predict families in the two reference periods. In order to limit the families to those with children, the PPR at parity zero was assumed to be equal to unity, eliminating entry sterility (married couples who were not able to conceive from the beginning of their marriage). This means that all couples in the model had at least one child. Finally, women were assumed to have completed reproduction and reached menopause by age 50, a common assumption in historical demography.[18]

Family size and the number of children being supported in the household at one time is also influenced by the birth spacing between each successive child. Wrigley *et al.* provide birth spacing estimates, which varied based on the age of the mother and the parity of the child.[19] It was impossible to account for all of this variation, so the mean birth spacing for all parities above 0 and all ages was used in the model: 32.59 months in 1650-99 and 30.80 months in 1750-99.[20] In addition, Monte Carlo simulation allows variables to fluctuate randomly based on distributions with certain characteristics. Therefore, the birth interval in the model was allowed to vary randomly within a lognormal distribution with a mean of Wrigley *et al.*'s value for each reference period and a standard deviation of one year. Wrigley *et al.* also found that the birth interval following an infant death was shorter than a normal interval, so the interval after an infant death was allowed to vary based on a lognormal distribution with a mean of 23.51 months for 1650-74 and 23.25 months for 1750-74 and with standard deviations of 0.5 years.[21] Lognormal distributions were used to model birth spacing because one would expect the distribution of birth intervals to be right skewed. The birth interval from marriage to the first birth, parity 0, was allowed to vary uniformly from 0.75 to 2 years.

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[17] Wrigley, *et al.*, *English Population History*, p. 403.
[18] Wrigley, *et al.*, *English Population History*, p. 359.
[19] Wrigley, *et al.*, *English Population History*, pp. 410, 433.
[20] Wrigley, *et al.*, *English Population History*, p. 447.
[21] Wrigley, *et al.*, *English Population History*, pp. 438-9

A final variable often associated with fertility is the age at marriage of both parents, though in the current model it only affects the mortality risk that parents face year to year because the PPRs used to predict births are not age-specific. Again lognormal distributions were used to predict the age at marriage of both parents because age at marriage was right skewed. The mean marriage ages of men and women were drawn from Wrigley *et al.* for both reference periods. Then lognormal distributions were defined in order to most closely match the cumulative frequency distributions of marriage ages described in Wrigley *et al.*[22] Although the distributions could not be replicated exactly, the mean, median, and first and ninth decile were matched to create a fairly similar distribution.

Mortality was also crucial in determining family size. Many births did not lead to a long-term increase in the consumption requirements of the household because the child died prematurely, and many births did not occur at all because one of the parents died before reaching menopause or sterility. To account for this, each child was given a probability of dying in every year until they left the household. These probabilities of dying were drawn from the Wrigley *et al.* reconstitutions, which had annual probabilities of death for the first five years and then five-year probabilities thereafter. The mortality rates apply only to legitimate births, so there is no conflict with the absence of illegitimate births mentioned above.[23] If the child died, the household no longer had to provide resources to the child and family consumption requirements decreased.

Likewise, each parent had an age and sex-specific mortality risk drawn from Wrigley *et al*. These age and sex-specific mortality risks are necessary because excess female mortality due to maternal mortality and other causes was a feature of historical populations.[24] Although Wrigley *et al.* do present some figures for maternal mortality, the age and sex-specific mortality rates employed already incorporated maternal mortality, so it was not possible to have a separate maternal mortality risk associated with each birth. In the model if the father dies, both his consumption and income leave the household and the wife is assumed to begin working, earning 50 per cent of the male wage. If the mother dies, her consumption is removed from the household but her death does not affect household income because in the model women do not work unless their husband is dead. These are heroic assumptions because of women's important household, non-market, and waged work, and it may be possible to relax these assumptions in later analysis.

Finally, the age at which children leave the household was also critical to the family's welfare over the family life cycle. Older teenagers were a substantial drain on resources, requiring more calories than adults. Therefore, if children left the household later, they were a much larger burden on the family. Children could leave the household in a number of ways: they could get an apprenticeship; become a servant in a different household; get married and form an independent household; or they could enter the workforce while remaining in the same household, earning at least their own consumption requirements and removing the household's need to support them. Mixing these four definitions is not ideal, but is perhaps the best method of dealing with this problem. The age at which children left the household

[22] Wrigley, *et al.*, *English Population History*, pp. 146-7.
[23] Wrigley, *et al.*, *English Population History*, pp. 250-51.
[24] McNay, *et al.*, 'Excess Female Mortality'.

was therefore allowed to vary based on a normal distribution with a mean age of leaving at 16 and a standard deviation of one year: this yielded a range of ages from 12 to 20. This age was assigned randomly to each child despite the sibling set size or the family's income. The net effect of these assumptions will be tested later in the paper.

The model produces results that are interesting at two levels. We can observe the changing welfare of individual families across the family life cycle as additional children are born, grow up, leave, and die. We can also study the distribution of median welfare ratios from 20,000 predicted families in each reference period. The results for each of these levels of analysis are presented in the next two sections with an additional section afterwards that performs some robustness checks on the results.

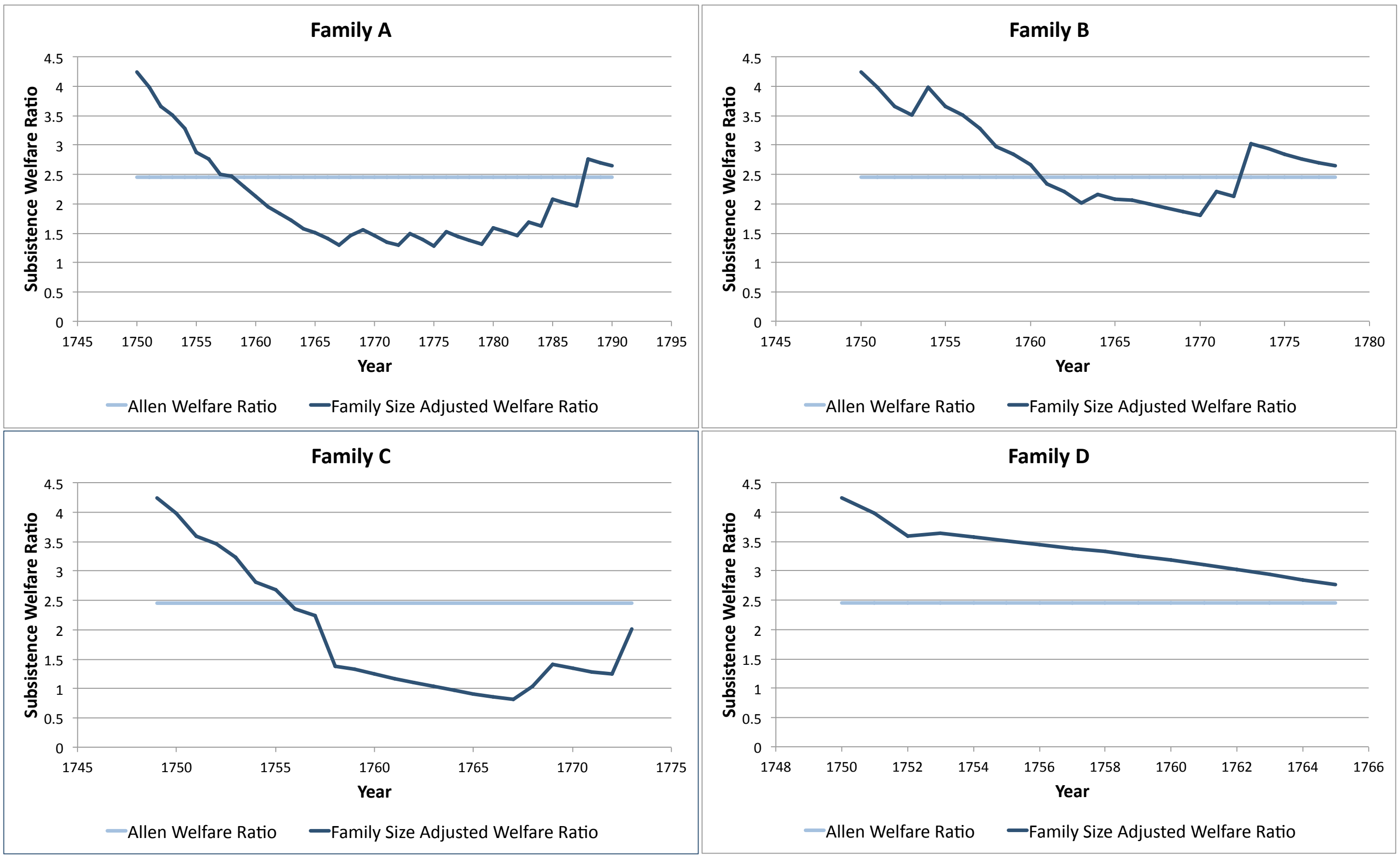
Family Life Cycle Results

The family life cycle results are perhaps best explained by looking at the welfare ratios across the family life cycle for several families. These families were not chosen to be representative but instead to highlight the effect of certain demographic characteristics and events on family welfare. For the sake of simplicity, these examples are drawn from the 1750 reference period, but the general findings are the same across both periods. Figure 1 shows the subsistence welfare ratio (dark blue) for Family A, which consisted of two parents and nine children with no fatalities before the maturity of the final child (see also Table 4). Allen's constant three consuming unit real wages are also displayed (light blue). With a median welfare ratio of 1.69 across the life cycle, the family falls well below Allen's subsistence welfare ratio of 2.45 for building labourers in 1750-1800.[25] The first two children had already left the household by the time the final (ninth) child was born, and this pattern continued as the other children aged and eventually left the household as well. Thus, the median number of children supported at any given time was only four children despite the nine children born in the household. This finding suggests that only accounting for the number of children born and not whether they are in the household at the same time could significantly skew the welfare ratios calculated for the family. It is also interesting that there do not appear to have been cyclical effects in the family's income based on pregnancy and lactation. The cyclical effects in Family A's welfare ratios after 1768 are upward spikes in the family's welfare ratios caused by children leaving the household, not by additional births. Finally, the family's welfare ratio changes drastically across the family life cycle from 4.24 when the parents first married to a minimum of 1.28 in 1775 when the family reached its peak consumption. Thus Allen's spot welfare ratio estimate hides significant variation in family welfare ratios across the family life cycle.

Figure 1 also shows the welfare ratios for Family B, a family with six children born, three surviving to leave the household, and both parents surviving until the final child left the household. Family B's welfare ratio follow a similar pattern to those of Family A, but Family B is much better off with a median subsistence welfare ratio of

[25] The distributions of family welfare ratios and children supported at one time tend to be skewed, so the median will be used throughout the paper as the best measure of central tendency for these variables.

Figure 1: Southern England building labourers subsistence welfare ratios (1750-1800) for four model families across the family life cycle.



Sources: Simulated results.

Table 4: Characteristics of example families in Figure 1 above.

	Family				
Characteristics	A	B	C	D	E
Total Children Born	9	6	4	1	1
Child Deaths	0	3	0	0	1
Death Year of Mother	––	––	––	––	––
Death Year of Father	––	––	1758	––	––
Median Welfare Ratio	1.69	2.70	1.34	3.36	4.24
Min Welfare Ratio	1.28	1.80	0.81	2.77	4.24
Median Number of Children Supported	4	2	3	1	1
Max Number of Children Supported	7	4	4	1	1
Length of Family Life Cycle (years)	41	29	25	16	2

Notes: Families were predicted using southern English building labourer's wages and the subsistence price basket from 1750-1800. Allen's welfare ratio is equal to 2.45 for the period.

Sources: Simulated results.

2.70, substantially above Allen's constant subsistence ratio for the period, 2.45. Family B highlights the importance of including childhood mortality in the calculations of family size and family welfare ratios. Despite the fact that six children were born in Family B, the median number of children being supported at any given time was two and the maximum number of children was only four. Likewise, child deaths could create sharp upward spikes in the family's welfare ratios because the family no longer had to feed the child: see the jump in the welfare ratio between 1753 and 1754 caused by the first child's death at age two. The effect of child deaths is smaller when the household is larger because the children made up a smaller percentage of the total family consumption requirements.

With a median welfare ratio of 1.34, Family C was one of the poorer families predicted from the 1750 Monte Carlo simulation, but it was not a particularly large family. It consisted of two parents and four children, all surviving to leave the household. The significant difference was that the father died eight years into the marriage, which removed both his consumption and his income from the family. This death is visible in Figure 1 from the sharp decline in the welfare ratios in 1758. As mentioned above the mother is assumed to have been able to earn half of the father's wage, but this still led to a substantial drop in the family's income: the father's death accounts for 25 per cent of the decline in the welfare ratio from peak to trough. The family's welfare ratio also remained low after the father's death until the first two children left the household. Family C therefore demonstrates the importance of including parental mortality when calculating the welfare ratios for families.

Families D and E represent the higher end of the distribution of median family welfare ratios. Family D was composed of two parents and one child who all survived the family life cycle. As shown in Figure 1, the family's welfare ratio declined steadily across the family life cycle, but it always remained above Allen's welfare ratio and yielded a high median welfare ratio of 3.36. Finally, Family E consists of a couple that were married and conceived a child, but the child died in infancy and the couple became sterile before the next birth. Thus, the family is only observed and measured as a family for two years and the median welfare ratios are very high. The proportion of families falling into this category could significantly alter the shape and central tendency of the income distributions.

In conclusion, the family life cycle results show a somewhat U-shaped pattern in welfare ratios over time for families. This is as expected because as a family grows and the children age, the resources needed to feed the family increase. Likewise, as children leave the household, their consumption needs are removed increasing the family's welfare ratio. The model, however, does not predict cyclical welfare shocks created by pregnancy and lactation because each child is added *gradually* to the family's consumption through pregnancy, breastfeeding, and thence independence.[26] Women needed very few additional calories (85 extra calories per day) in the first trimester of pregnancy. This extra consumption gradually increased throughout pregnancy and nursing until weaning when the child's consumption ceased to be provided through the mother and was added directly to the family's consumption. Therefore, the additional costs of feeding the mother during pregnancy and lactation did not have a strong cyclical impact on family welfare ratios. However, there could have been other costs for new clothing, a midwife, and in lost productivity during

[26] Humphries, 'Lure', p. 13.

pregnancy and nursing, which were not measured as a part of the model. The clear message from the results is that the cost of each new child drove the male breadwinner family closer to subsistence.

Monte Carlo Simulation Results

While the picture painted of individual family's welfare ratios over the family life cycle is instructive of the welfare consequences of certain demographic events, in order to understand whether family size mattered more generally, it is necessary to understand how these demographic events affected the distribution of welfare ratios in society as a whole. Therefore, Monte Carlo simulation was used to predict 20,000 model families. This yielded realistic distributions of several variables that help to explain the complex interaction between fertility and mortality characteristics, family size, welfare ratios and, in the end, real wages.

Table 5: Demographic predictions of the Monte Carlo simulations.

	1650-1700	1750-1800
Mean of Predicted Distribution of Median Children Supported	2.01	2.29
Median of Predicted Distribution of Median Children Supported	2.00	2.00
Coefficient of Variation of Distribution of Median Children Supp.	0.4134	0.3868
Mean of Predicted Distribution of Max Children Supported	3.01	3.58
Median of Predicted Distribution of Max Children Supported	3.00	4.00
Max of Predicted Distribution of Max Children Supported	9.00	9.00
Mean Total Children Born per Family	3.89	4.66
Completed Family Size (Humphries)	––	5.46
Computed Sibling Group Size (Humphries)	––	7.48

Sources: Simulated results and Humphries, 'Lure', p. 18. See also Humphries, *Childhood*, p. 57.

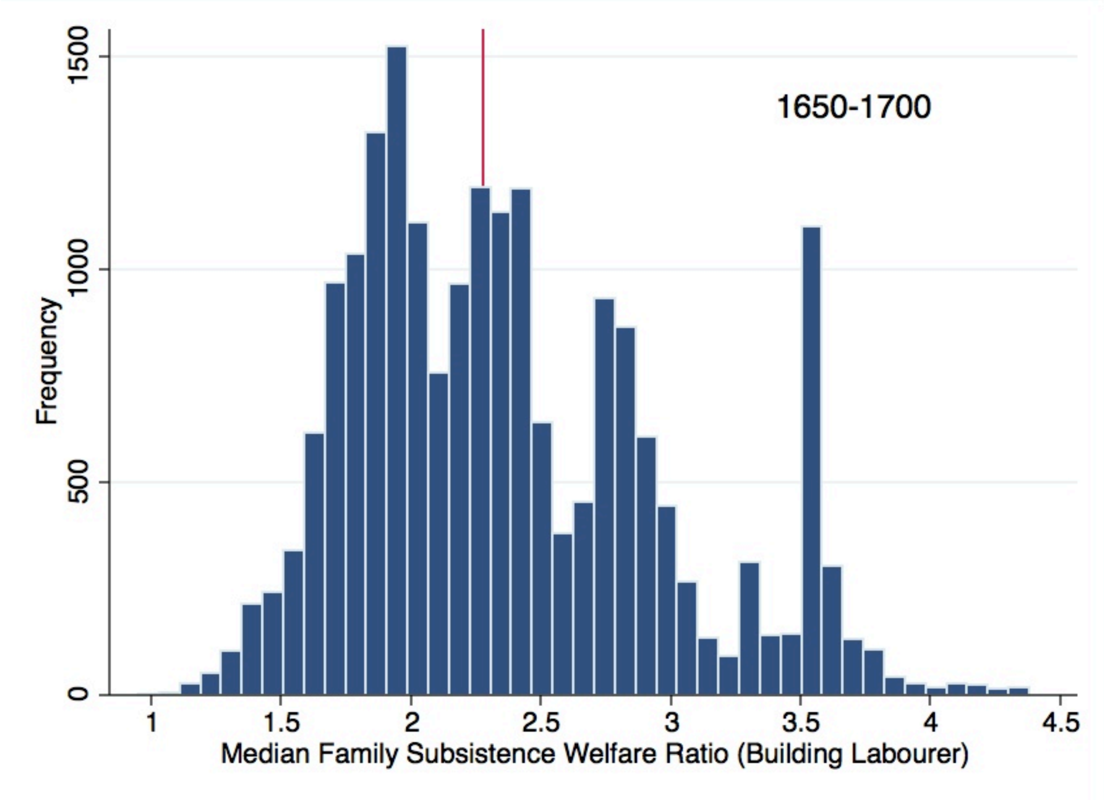
The first thing to note is that family size was generally much lower than historians have thought, especially if family size is only considered to be the number of children being supported by the household at the same time. Because the distribution of children being supported by an individual household was not always normal, the median provided the best measure of central tendency at the household level. Thus, the mean value for the distribution of median children being supported at one time was 2.01 in the period 1650-1700 and 2.29 in the period 1750-1800 (Table 5). The mean value was lower in the first reference period because the parity progression ratios (PPRs) were lower, more women were becoming sterile; parents got married later giving them less time to have children; and birth spacing of children was slightly longer. The lower number of children born per family in the period 1650-1700 corroborates the importance of these fertility differences. Mortality also played a role though; mortality rates were higher for both children and adults in the seventeenth century. Birth spacing was not only important in limiting the number of children women could have before reaching menopause, but it also had the effect of spreading the burden of additional children over a number of years, which further reduced the number of children being supported at any one time.

The maximum number of children being supported by the family at one time also provides insight into the distribution of family size. Even these figures are substantially lower for both periods than might be expected: the mean of the predicted distribution of maximum children supported was 3.01 for 1650-1700 and 3.58 for 1750-1800. While up to nine children could be cared for in a single household at one time, the average figures were much lower, showing how strong the birth spacing and mortality effects could be. Thus, the number of children being supported at any time was substantially smaller than the completed family size or sibling group size measures used by Humphries to criticize Allen's method. However, the number of children being supported is also a somewhat misleading characteristic because as described above, some children required more of the household's resources than others. Thus, the consuming unit weighted welfare ratio is the best measure of the family's well being.

Before discussing the summary statistics of the distributions, it is first necessary to understand the shape and composition of the distribution of median welfare ratios (Figures 2 and 3). The distributions appear to be right skewed and multimodal. The various modes are associated with certain types of families that are more likely to exist than others. The spike at a median welfare ratio just above 3.5 in 1650-1700 and around 4.25 in 1750-1800 is associated with two types of families. One type of family had one child that survived to maturity but the mother died shortly after the child's birth. The other type, similar to family D above, had one child or a number of children who died in infancy after which the couple became sterile. These types of families were more common in the first reference period because mortality rates of mothers and children were higher and because the PPR at parity one was lower, creating higher rates of subsequent sterility.

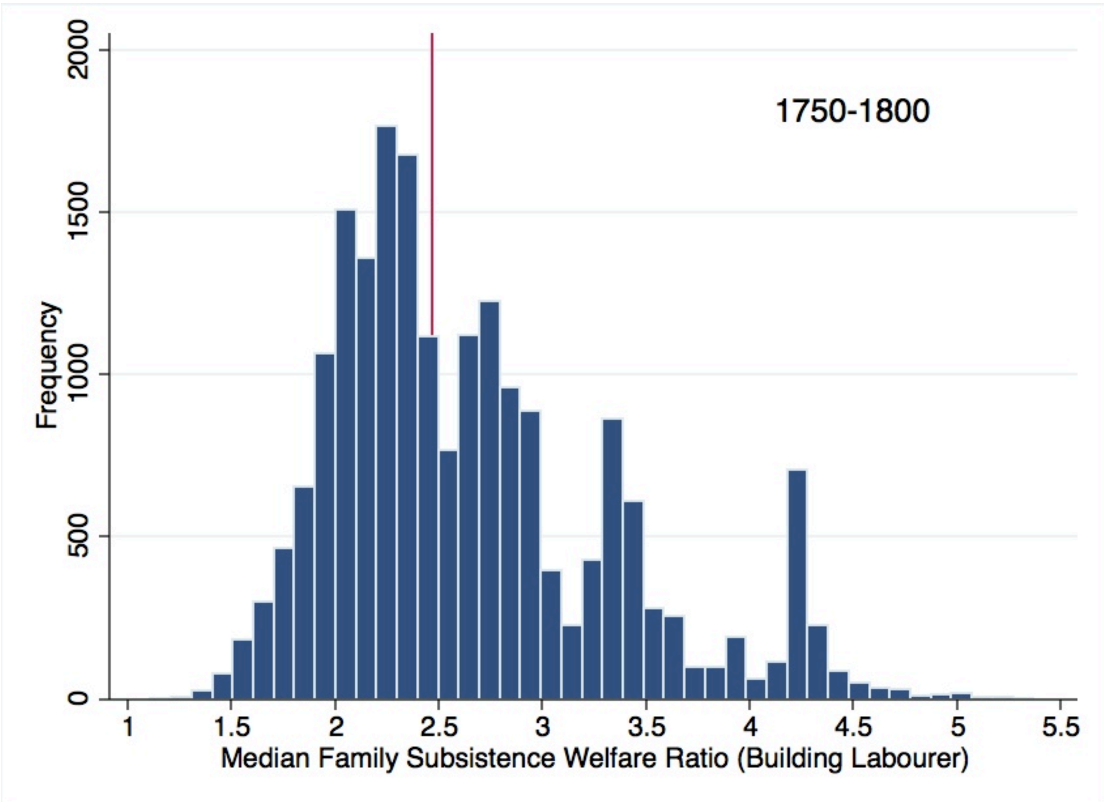
The cluster of median welfare ratios around 2.75 in 1650-1700 and around 3.25 in 1750-1800 is associated with families supporting one child at a time where both parents survive or a father supporting two children at a time. Again this cluster is larger in the period 1650-1700 because of lower fertility and higher mortality rates. The next modal cluster around a welfare ratio of 2.35 in 1650-1700 and around 2.75 in 1750-1800 is associated with families with a median of two children being supported at a time, mothers supporting one child alone, or fathers supporting three children alone. The final cluster just above two in 1650-1700 and around 2.25 in 1750-1800 consists of families supporting a median of three children at any given time, mothers supporting two children, and fathers supporting four children. This cluster was much larger in 1750-1800 than before because fertility had increased and mortality had decreased creating larger families. The left tail mainly consisted of widows supporting a median of three or four children, but there were also families with two parents supporting five children at a time with a maximum of nine in the household at the same time. The right tail was associated with widowers supporting one child.

Figure 2: Distribution of Median Family Subsistence Welfare Ratios for Southern English Building Labourers in 1650-1700 (median displayed as red line).



Sources: Simulated results.

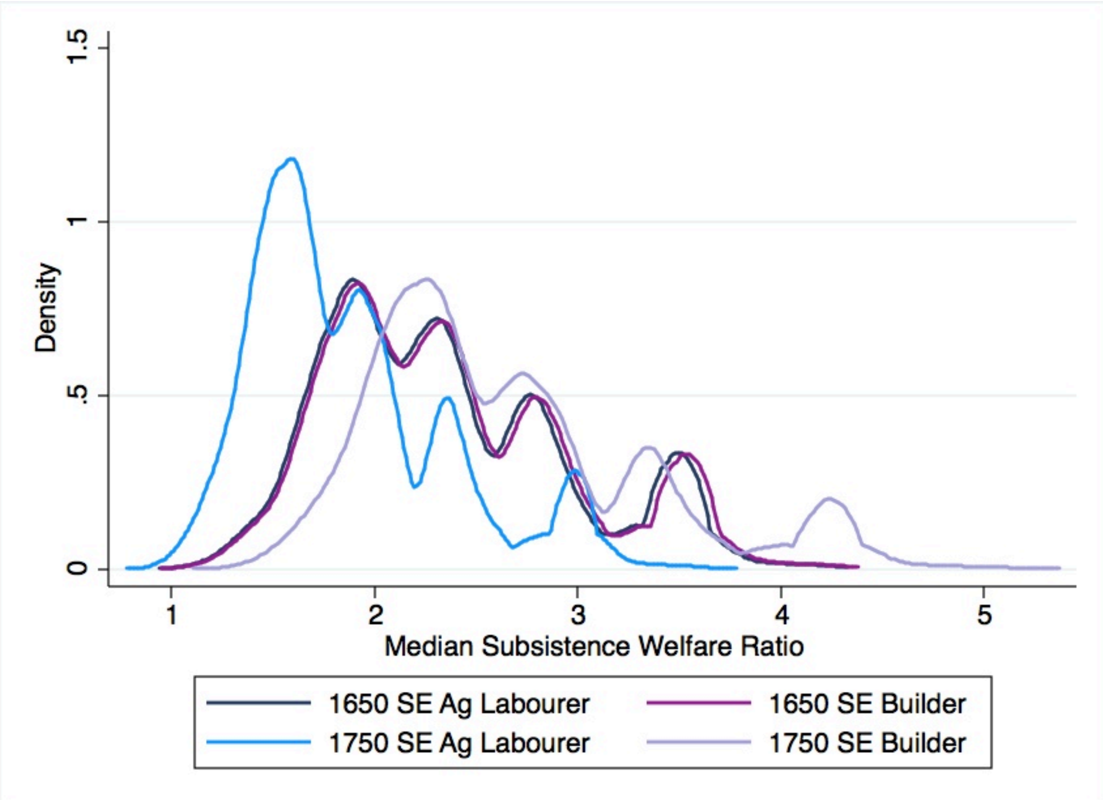
Figure 3: Distribution of Median Family Subsistence Welfare Ratios for Southern English Building Labourers in 1750-1800 (median displayed as red line).



Sources: Simulated results.

The discussion above has focused on southern English building labourers' subsistence welfare ratios in both reference periods, but the distributions are the same, although condensed somewhat, for the southern England agricultural labourers' subsistence welfare ratios and the respectability welfare ratios. Figure 4 shows several overlapping kernel density plots that compare the distribution of welfare ratios for agricultural and building labourers in both reference periods. Figure 5 does the same for the respectability welfare ratio distributions. In the period 1650-1700, the agricultural and building labourers' wage distributions were nearly identical, but they diverged significantly over the following hundred years with building labourers doing substantially better than agricultural labourers.

Figure 4: Predicted distributions of median family subsistence welfare ratios of agricultural labourers and building labourers in southern England.



Sources: Simulated results.

There was also change in the centres and dispersions of the distributions over time (Table 6). Because the distributions of median family welfare ratios are not normally distributed and are multi-modal, the median is the best measure of central tendency. The median of the median agricultural labourer's family subsistence welfare ratio was 2.02 in 1650-1700 but declined to 1.73 by 1750-1800. Agricultural labourers' welfare ratios declined substantially because their wages increased only by 5.72 per cent between the two periods which was not enough to keep pace with the increasing cost of the subsistence basket (23.68 per cent) and increasing family sizes (14.01 per cent). In addition, the percentage of total family years lived below the subsistence level – a subsistence welfare ratio of one – increased from 1.92 per cent in 1650-1700 to 6.09 per cent in 1750-1800. This evidence thus suggests that increases in family size exacerbated the low wage growth experienced by English agricultural labourers across the early modern period to the point that six per cent of the population was starving.

The median of the median building labourer family subsistence welfare ratios was 2.28 in 1650-1700 and increased to 2.47 by 1750-1800. This increase was caused by an upward shift in the distribution: nominal day wages of building labourers in southern England increased by 48.38 per cent between the two periods (Table 3). Unlike agricultural labourers, the increase in building labourer's wages in southern England was large enough to overcome the rising cost of the subsistence basket (23.68 per cent) and the increase in the number of children supported in the household (14.01 per cent). Building labourers were also largely able to avoid subsistence crises with only 1.80 per cent of family years lived by all predicted families falling below unity in 1650-1700. This figure fell with improving conditions in the eighteenth century. In addition, the changing demographic characteristics between the two periods did not significantly alter income inequality ; the Gini coefficient was around 0.14 in both periods.

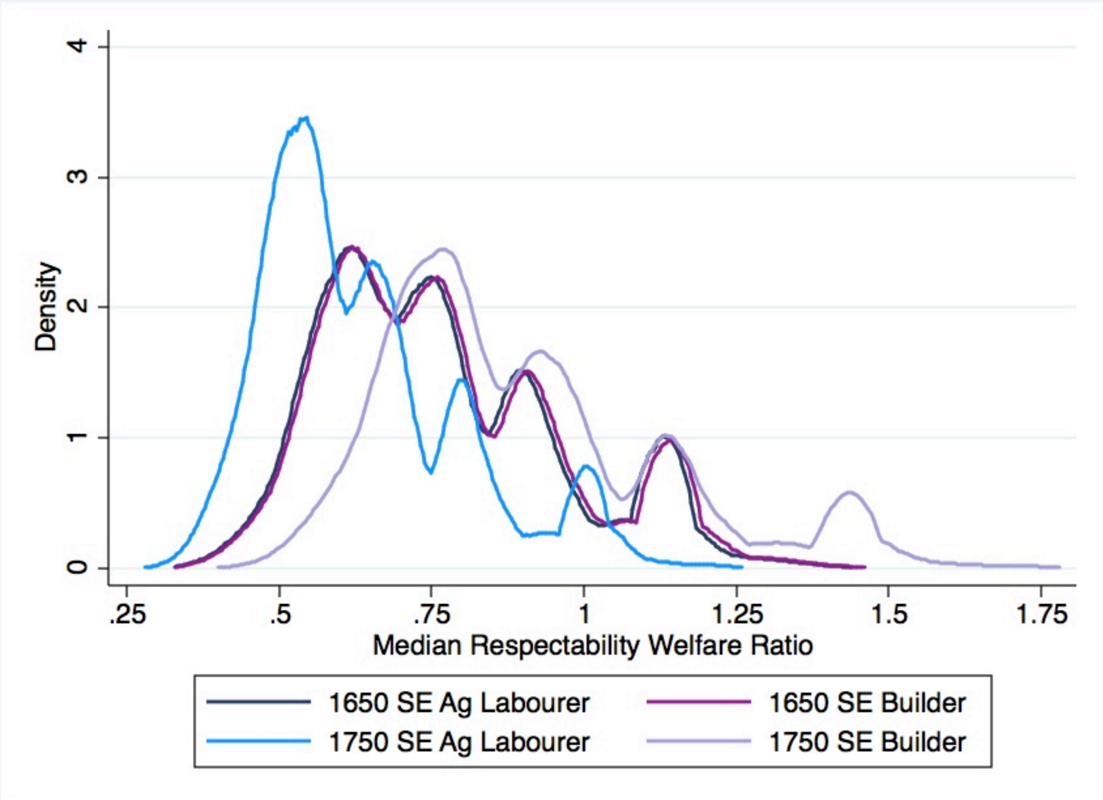
Table 6: Descriptive statistics for distributions of predicted median family subsistence welfare ratios of agricultural labourers and building labourers in southern England.

	Southern England Agricultural Labourers		Southern England Building Labourers	
	1650-1700	1750-1800	1650-1700	1750-1800
Allen Subsistence Welfare Ratio (WRs)	2.02	1.73	2.04	2.45
Median of Predicted Distribution of Median WRs	2.25	1.74	2.28	2.47
Mean of Predicted Distribution of Median WRs	2.35	1.86	2.37	2.65
Min of Predicted Distribution of Median WRs	0.94	0.78	0.95	1.11
% of Total Family Years Below Subsistence	1.92%	6.09%	1.80%	0.77%
Gini Coefficient	0.1422	0.1410		

Sources: Simulated results.

The median family respectability welfare ratios paint a largely complementary picture to the subsistence distributions already described. Again the distributions of building labourer and agricultural labourers' welfare ratios were similar in 1650-1700 but diverged in the eighteenth century. The median agricultural labourer respectability welfare ratio declined from 0.66 in the late seventeenth century to 0.59 in the late eighteenth century (Table 7). This decline was caused by both a downward shift in the distribution and the changing shape of the distribution. The sluggish, 5.72 per cent increase in agricultural labourers' nominal day wages was far short of the 18.74 per cent increase in the cost of the respectability basket and the 14.01 per cent increase in the number of children being supported. The percentage of total family years lived by the predicted families under the respectability value of one also increased from 83.42 per cent to 92.75 per cent between the two periods highlighting the changing shape of the distribution. The median building labourer respectability ratio increased across the two periods from 0.67 to 0.84. The buoyant increase in southern English building labourers' nominal day wages of 48.38 per cent again exceeded the 18.74 per cent increase in the cost of the respectability basket and the 14.01 per cent increase in the number of children being supported. The percentage of family years spent below the respectability level also declined from 82.47 per cent to 63.31 per cent. Finally, inequality as measured by the Gini coefficient was remarkably stable despite the changes in the shape of the welfare ratio distribution between the two periods.

Figure 5: Predicted distributions of median family respectability welfare ratios of agricultural labourers and building labourers in southern England.



Sources: Simulated results.

These distributions can also be compared to Allen's original welfare ratios to see whether his welfare ratios overstate or understate the demography-adjusted ratios. The distributions show that that Allen's welfare ratios are nearly identical to the predicted medians in the period 1750-1800, but Allen's welfare ratios for 1650-1700 are lower than the demography-adjusted ratios because the average consuming unit burden on the family was less than the three consuming units that he assumed. This suggests that Allen's three consuming unit family was not a bad estimate and likely understates the median real wage of labourers rather than overstating it as Humphries has suggested.[27] It is possible that with the increase in fertility and decrease in mortality at older ages and in childhood across the nineteenth century, there could be a point where the median consuming units per family exceeded Allen's three consuming unit basket. However, at least for the preindustrial period, it is unlikely that Allen's welfare ratios would overestimate the demography-adjusted welfare ratios.

[27] Humphries, 'Lure'.

Table 7: Descriptive statistics for distributions of predicted median family respectability welfare ratios of agricultural labourers and building labourers in southern England.

	Southern England Agricultural Labourers		Southern England Building Labourers	
	1650-1700	1750-1800	1650-1700	1750-1800
Allen Respectability Welfare Ratio (WRs)	0.66	0.59	0.67	0.83
Median of Predicted Distribution of Median WRs	0.73	0.59	0.74	0.84
Mean of Predicted Distribution of Median WRs	0.76	0.63	0.77	0.90
Min of Predicted Distribution of Median WRs	0.33	0.28	0.33	0.40
% of Total Family Years Below Respectability	83.42%	92.75%	82.47%	63.31%
Gini Coefficient	0.1413	0.1404		

Sources: Simulated results.

Robustness Checks and Potential Biases

Modelling the full variation of family size and structure is inherently impossible, so it is important to understand how the simplifications and assumptions in the model affect the final outcomes. Therefore, a number of robustness checks have been carried out to test the assumptions. When robustness checks were not possible, the potential nature of the bias and its effect on the median of the welfare ratio distribution and on income inequality is explained so that the potential bias is clear. This section will treat four potential issues in turn: the age at leaving the household, remarriage, women and children's labour force participation, and illegitimacy.

Determining the age at which children should leave the household is a difficult proposition. Currently the leaving age is allowed to vary over a normal distribution with a mean of 16 and a standard deviation of one year, but small adjustments to this distribution could have a potentially large influence on the median welfare ratio distributions, especially since children in their late teens are especially burdensome on family resources. I have therefore re-simulated the model for the distribution of building labourers' respectability welfare ratios in 1750-1800 assuming the mean leaving age was 14 or 18. The results are presented in Table 8. Clearly, the age at which children left the household could have a large effect on the median welfare ratio, the years spent below the respectability level, and the income inequality created by differences in family size and structure. If children left the household later, the median welfare ratio decreased, the percentage of family years spent below the respectability level increased, and the income inequality also increased. Setting the appropriate level is difficult because there is very little representative evidence based on a large sample of households. Therefore, an average age of children leaving the household at 16 seems best.

Table 8: The influence of changing the age at which children left the household on the distribution of southern English building labourers' median respectability welfare ratios.

	Mean Age of Children Leaving		
	14	16	18
Allen Respectability Welfare Ratio (WRs)	0.83	0.83	0.83
Median of Predicted Distribution of Median WRs	0.89	0.84	0.80
Mean of Predicted Distribution of Median WRs	0.93	0.90	0.87
Min of Predicted Distribution of Median WRs	0.42	0.40	0.38
Mean of Dist. of Median Children Supported	2.19	2.29	2.38
% of Total Family Years Below Respectability	60.65%	63.31%	65.49%
Gini Coefficient	0.1282	0.1404	0.1504

Sources: Simulated results.

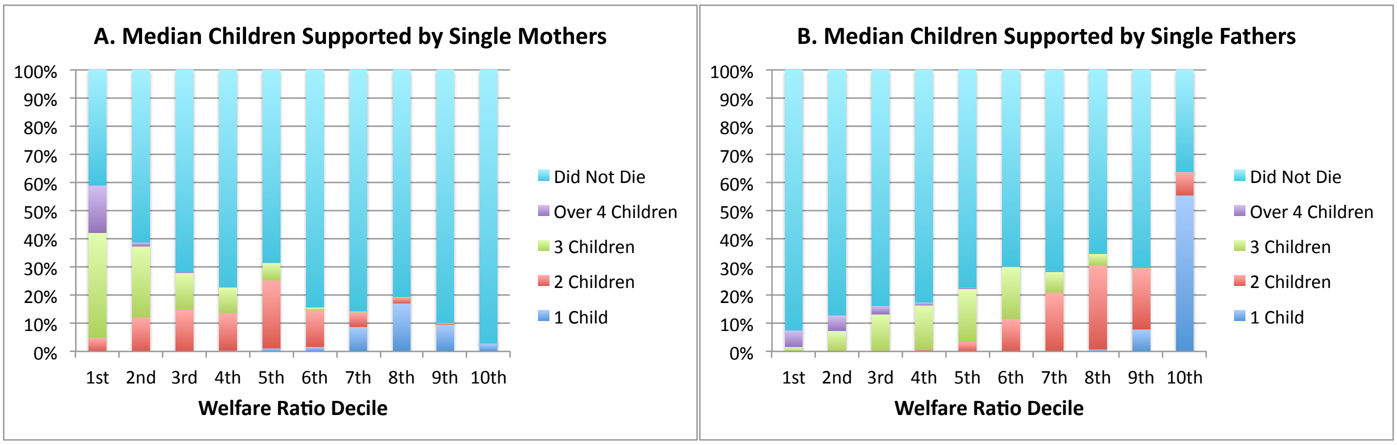
It might also be desirable to partially endogenize the process through which children left. This would allow families with lower median welfare ratios to send their children to apprenticeships or out to work at younger ages than the children of their wealthier counterparts. This, however, is quite difficult. There is little evidence about the timing of children leaving the home upon which to draw. Humphries provides some evidence for when children started working or were apprenticed, but the relative frequency with which apprenticeships and employment were available is harder to establish.[28] Likewise, it is difficult to pick a threshold poverty line under which families would send their children out sooner. The respectability line might serve as a good point of reference, but with 63 to 82 per cent of southern English family years spent below the respectability threshold, it would not serve as a good demarcation point for that population. Although it is not possible to carry out a specific robustness check at this point, it is possible to understand how allowing children from poorer families to leave the household earlier would affect the distribution. If poorer children left earlier, then families at the lower end of the distribution would have smaller consumption requirements, raising their welfare ratio and moving them toward the right in the distribution. This would likely shift the median upwards and decrease income inequality in the population.

Not allowing remarriage is another potentially problematic assumption in the model. As it stands, single parent households are overrepresented in the distribution because some of the single parents would have gotten remarried either bringing the higher income of a male earner back into a single mother's family or increasing the consumption requirements of a single father's family through the new wife's consumption and the birth of more children. This picture however oversimplifies the problem. Because women do not add to family income in the model and once they die no additional children can be added to the family, the mother's death is positively associated with the welfare ratio. Thus, in Figure 6B, single fathers are

[28] Humphries, *Childhood*, pp. 203-7, 258-63.

disproportionately represented in the upper deciles of the welfare ratio distribution. The opposite is true for single women (Figure 6A). Single mothers are disproportionately represented in the lower deciles of the welfare ratio distribution because they had to support their families on half of the male income.

Figure 6: Median children supported by families where one of the parents died across different welfare ratio deciles 1750-1800.



Notes: Single mothers and fathers refer to families where the mother or father died before the end of the family life cycle.

Sources: Simulated results.

Single father and single mother households were also different in another important respect. Most single fathers lost their wives early in their marriage when they had a smaller family. Single mothers lost their husbands well into their marriages when they had much larger families to support. These women were poor because they had many children while their husbands were still alive, and then their husbands died when the household was at its peak consumption requirement (see Family C above). This difference is important because it affected the desirability of the single parents when remarrying. Wrigley *et al.* found that controlling for period, age, and occupational type, widows with no dependents were usually remarried in 29.1 months whereas widows with four or more dependents were remarried in 63.1 months, over five years. This discrimination, however, was non-existent for widowers. The remarriage interval for widowers did not substantially differ across the number of dependents, and the effect was not statistically significant.[29] Thus, including remarriage in the model would likely shift the median downward. Widowers and widows with fewer dependents in the upper deciles would remarry and have additional children, lowering their welfare ratio. Introducing remarriage would decrease the income inequality in the distribution, though, because the dispersion of welfare ratios would decline.

As a preliminary estimate of what the net effect of adding remarriage would be, I have incorporated widower/spinster marriages into the model. These are the easiest marriages to model because according to the remarriage interval evidence, neither the widower's age nor the number of dependents in the household affected the remarriage intervals.[30] Thus, all widowers can be given an equal probability of being

[29] Wrigley *et al.*, *English Population History*, p. 180.
[30] Wrigley *et al.*, *English Population History*, p. 180.

remarried, and the difficult remarriage selection issues surrounding widows can be avoided. In incorporating widower/spinster marriages into the model, most of the assumptions in the original model could be held the same: the second wife was subjected to the same annual probability of death based on her age as the first wife; child mortality rates were the same; and the method for estimating the age at which children left the household was the same. In addition, the consequences of child and parental mortality of both first and second wives were held the same.

However, there were four additional modifications necessary. First, the age at marriage of the second wife was allowed to vary over a normal distribution with means at the average age of women in widower/spinster marriages from Wrigley *et al.* and a standard deviation of four years. The mean age at marriage of women in widower/spinster marriages, 29.5 in 1650-1700 and 28.5 in 1750-1800, was significantly higher than the mean age of women in bachelor/spinster marriages, so it was important to take this into account.[31] Second, it was necessary to make assumptions about the remarriage interval because remarriage was not instantaneous. Remarriage intervals were taken from Wrigley *et al.*'s regression analysis, so the intervals for the different periods are independent of the widower's age, number of dependants, and occupation. In 1650-1700 the remarriage interval was 27.9 months, and in 1750-1800 the interval was substantially longer at 35.8 months.[32] These intervals were allowed to fluctuate over normal distributions with standard deviations of 6 months in order to add variation to the model. Third, fertility, the parity progression ratios (PPRs), had to be lowered slightly. Because fertility declines strongly with age, fertility had to be lower for the older women in widower/spinster marriages than women in bachelor/spinster marriages.[33] In addition, the PPR at parity zero was set at the normal rate in order to introduce entry sterility into the model. A PPR of one at parity zero ensured that all bachelor/spinster married couples had children, but when incorporating remarriage into the model, it is no longer necessary to uphold this assumption. Thus, some women in widower/spinster marriages entered the marriage infertile.

Finally, if all widowers were remarried, the impact of remarriage would have been highly overstated in the robustness check. Determining the frequency of remarriage, however, is incredibly difficult. Wrigley *et al.* were very pessimistic about the reliability of their data on the relative frequency of bachelor/spinster, bachelor/widow, widower/spinster, and widower/widow marriages. Bachelor/spinster marriages were overrepresented in the reconstitution data, and the various other types of marriage were underrepresented in different ways. Their figures were also reliant on the number of connections that could be made in the reconstitution forms, which created substantial discrepancies between the relative frequencies calculated for men and women when they should have been equal. And even if these frequencies were taken to be reasonably reliable, they do not account for the relative desirability of different widowers and widows as described above. Fortunately, for widower/spinster marriages it seems that only the time period and the occupation of the widower were

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[31] Wrigley *et al.*, *English Population History*, p. 149.
[32] Wrigley *et al.*, *English Population History*, p. 180.
[33] Wrigley *et al.*, *English Population History*, p. 403. Holding the PPRs constant for both bachelor spinster and widower spinster marriages only led to a difference of around 0.02 in the final median welfare ratios.

significant in explaining the remarriage interval.[34] Therefore, the average ratio of widower/spinster to bachelor/spinster marriages in the two reference periods can tentatively be applied to limit remarriage to a reasonable level: 14.47 per cent in 1650-1700 and 9.45 per cent in 1750-1800. Thus, all widowers were given a certain probability of remarriage, which limited widower/spinster marriages to the appropriate level.

Table 9: Comparison between the descriptive statistics for the original distribution and remarriage adjusted distribution of predicted families.

	1650-1700 Building Labourers		1750-1800 Building Labourers	
	No Remarriage	Remarriage	No Remarriage	Remarriage
Allen Subsistence Welfare Ratio (WRs)	2.04	2.04	2.45	2.45
Median of Predicted Distribution of Median WRs	2.28	2.22	2.47	2.43
Mean of Predicted Distribution of Median WRs	2.37	2.30	2.65	2.59
% of Total Family Years Below Subsistence	1.80%	1.81%	0.77%	0.74%
Gini Coefficient	0.1422	0.1340	0.1410	0.1318
Mean of Dist. of Median Children Supported	2.01	2.03	2.29	2.31
Mean of Dist. of Max Children Supported	3.01	3.15	3.58	3.67
Mean Total Children Born per Family	3.89	4.15	4.66	4.89
% Single Father Families	30.95%	16.84%	26.64%	16.94%
% Single Mother Families	28.30%	30.99%	24.43%	25.81%
% Families where Father Remarried	—	14.79%	—	9.32%
% of Families where Both Parents Survived	40.76%	37.39%	48.94%	47.94%

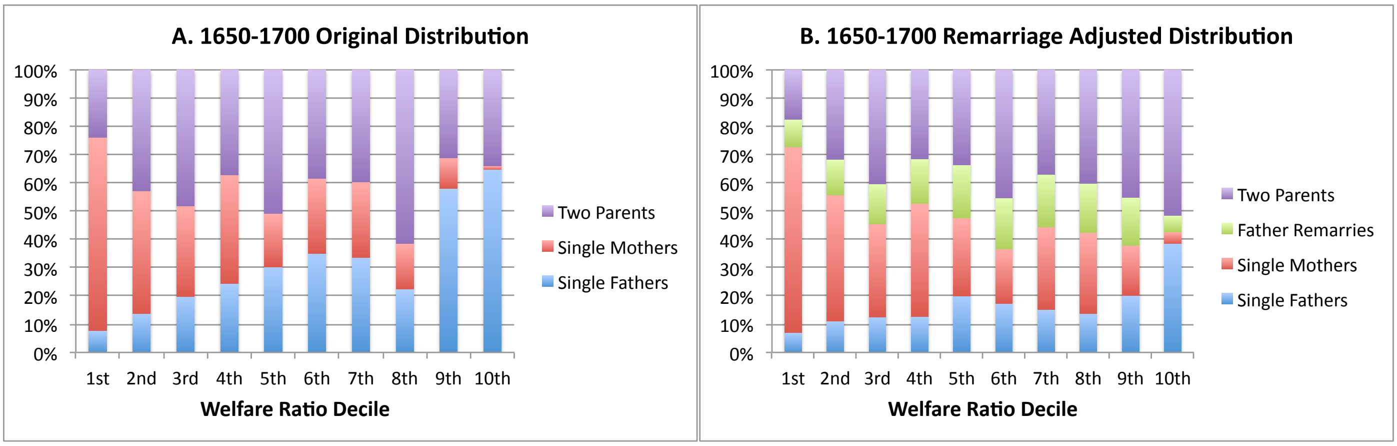
Sources: Simulated results.

Table 9 shows the effect of remarriage on distribution of building labourers' wages. In the period 1650-1700 female mortality rates were substantially higher, so a larger percentage of families lost the mother before the end of the family life cycle. The average ratio of widower/spinster to bachelor/spinster marriages was also higher at 14.47 per cent. Thus one would expect the impact of remarriage to be larger in the first period. This is indeed the case, but the remarriage effect is quite small in both periods. In the first period remarriage reduced the median of the predicted distribution of welfare ratios by 0.06 from 2.28 to 2.22. This decreased welfare ratio is still much higher than the welfare ratio that Allen would have predicted, 2.04. In 1750-1800, the ratio of widower/spinster to bachelor/spinster marriages was lower, 9.45 per cent, and the decrease in the median welfare ratio due to remarriage was also smaller, a decrease 0.04 from 2.47 to 2.43. This decrease was not large enough to substantially shift the median below Allen's welfare ratio of 2.45 for the later period. Remarriage did not seem to affect the percentage of total years lived beneath subsistence either, but it did decrease the inequality by reducing the number of single father households at the top end of the distribution. This shift is especially clear when comparing the percentage of single father households in the upper welfare ratio deciles for the original distribution 1650-1700 and the remarriage adjusted distribution (Figure 7). Figure 8 compares the 1650-1700 original and remarriage adjusted distributions on a kernel density plot showing that remarriage increased the

[34] Wrigley, *et al.*, *English Population History*, pp. 164-6, 180.

relative frequency of larger families in the modal clusters around 1.75 and 2.25 and decreased the modal cluster around 3.5. In terms of family size, remarriage significantly increased the number of children born per family, counting both wives in the same family. It also increased the maximum number of children being supported at any given time. However, the effect on the median number of children supported was much smaller, a difference of two or three hundredths.

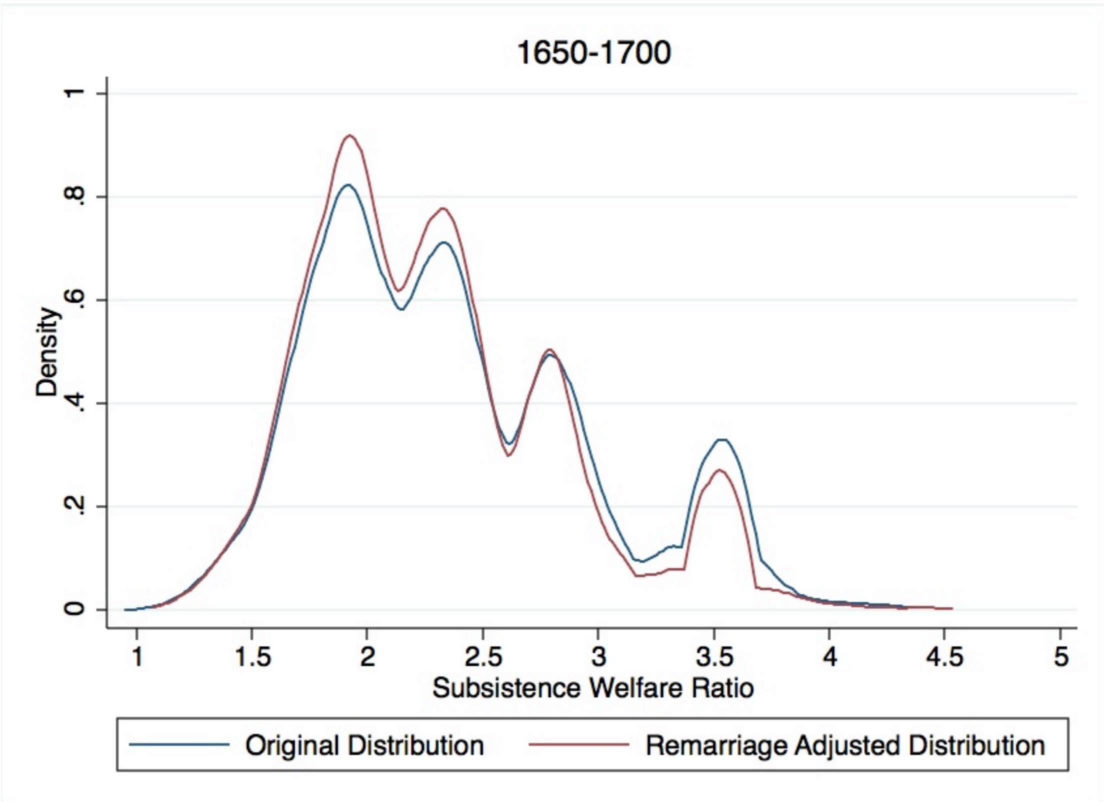
Figure 7: Comparison of the frequency of two parent and single parent families across welfare ratio deciles between the original predicted distribution and the remarriage-adjusted distribution.



Notes: Single mothers and fathers refer to families where the mother or father died before the end of the family life cycle.

Sources: Simulated results.

Figure 8: Comparison of the original and remarriage-adjusted distributions of median welfare ratios.



Sources: Simulated results.

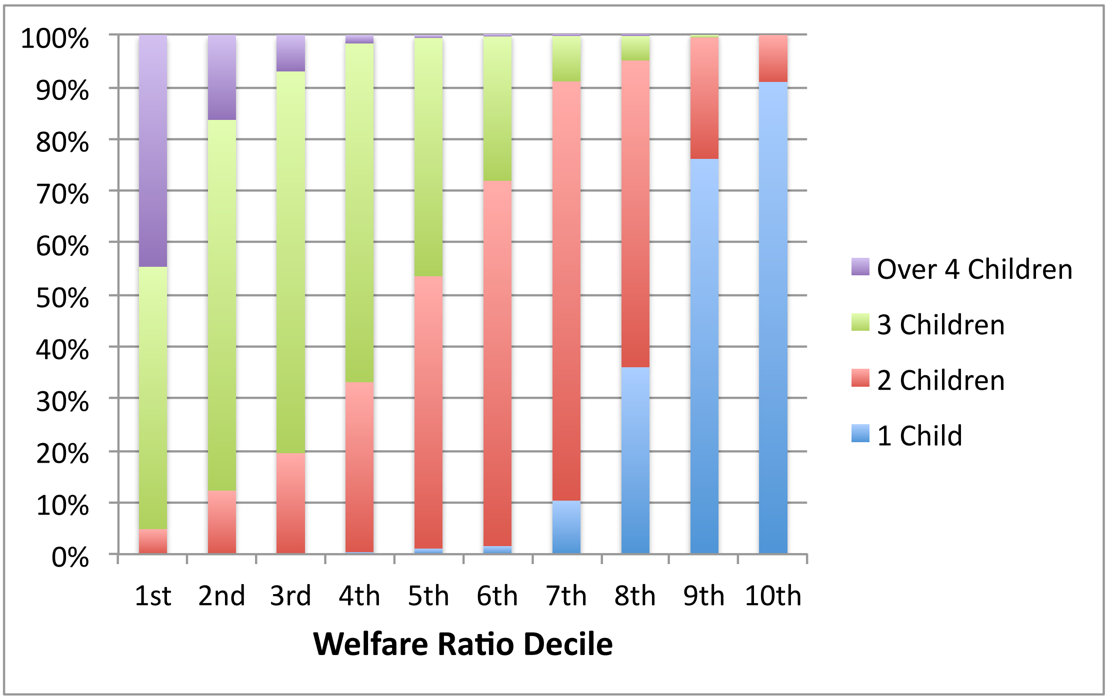
The effect of remarriage on the distribution of welfare ratios was relatively small for several reasons. First, remarriage took time, increasing the difference in age between the children of the first and second wives. Thus, the burden of children was spread out over a longer period of time, and the median number of children supported did not increase substantially. Second, many widowers did not get remarried. Only 46.75 per cent of widowers in 1650-1700 and 35.47 per cent of widowers in 1750-1800 were remarried. With such low rates of remarriage, there were still a lot of single father households in the upper deciles of the distribution. Finally, a small but important minority of the second wives entered the marriage infertile or died relatively young before they could have a number of children. These conclusions are very tentative because the precise nature of remarriage is unclear from the historical sources. In addition, this exercise did not incorporate bachelor/widow and widower/widow marriages. However, these other marriages, as far as we can tell, occurred much less frequently than widower/spinster marriages because the ratios of bachelor/widow and widower/widow to bachelor/spinster marriages were around three per cent. Thus incorporating these other marriages would be unlikely to lower the median welfare ratio substantially.

Another potential source of bias in the model is that it does not allow for women or children's labour force participation. Women and children did work in the early modern period and their income could serve as a helpful smoothing mechanism as the family's consumption requirements grew. In fact, Horrell *et al.* found that families' incomes increased across the family life cycle by sending children to work, compensating somewhat for the increased consumption requirements of the household.[35] However, introducing children and women's work into the model is incredibly difficult. There is very little information about women's labour force participation before the 1850 census, which enumerated both men and women's work. Horrell and Humphries found a labour force participation rate of 65.7 per cent based on 196 households surveyed in the period 1787-1815.[36] When aggregate or more census-like evidence is available, women's labour force participation rates were incredibly variable. Saito found that married female labour participation could be as high as 67.5 per cent in the late eighteenth century in the parish of Cardington, Bedfordshire, which had prevalent employment in cottage industries such as spinning and lace making. However, in the parish of Corfe Castle, Dorset, Saito found that married women's labour participation rate was only 8.7 per cent.[37] Even in 1851 female labour participation rates varied from 20 per cent to over 90 per cent in different parts of the country.[38] Therefore, at a national scale it is difficult to pick a level of women's labour force participation. Children's labour is equally as tricky because it varies based on age and gender. Saito generally found that male child labour participation was lower for the age groups 5-14 than female labour force participation, but this trend was not as clear for children age 15 and above. Saito's evidence from Cardington and Corfe Castle does clearly show that there was high labour force participation for children over 15 of both sexes averaging 82.15 per cent across the two parishes.[39] This suggests that it was not uncommon for children to

[35] Horrell, *et al.*, 'Destined for Deprivation', p. 345.
[36] Horell and Humphries, 'Women's Labour Force Participation', p. 98.
[37] Saito, 'Who Worked When', p. 221.
[38] Shaw-Taylor, 'Diverse Experiences', pp. 44-5.
[39] Saito, 'Who Worked When', p. 221.

work and that their income could have provided important additional resources to the household as their consumption reached a peak in their late teens.

Figure 9: Median number of children supported at one time by welfare ratio decile in 1750.



Sources: Simulated results.

Labour force participation, however, is only one part of incorporating the earnings of women and children into the model. There is also the problem of deciding which women and children should work. The easiest way forward would be to give every child and woman the same probability of being engaged in the labour force, but this is not entirely satisfactory since children from poorer families would likely have higher labour force participation rates than children from wealthier families. Likewise, one would have to decide when children went to work. Humphries has shed considerable light on the factors influencing the age at which male children started work. She found that there was a U-shaped trend over time with higher ages of starting work in the eighteenth and late nineteenth centuries than in the early nineteenth century. The father's occupational group also made a significant difference. Children from larger families, from families where the father was dead or absent, and from families receiving poor relief also started work earlier.[40] Finally, there is the issue of how much remuneration, as a percentage of the male wage, that women and children were able to earn. This changed over time, by occupation, and by sex of the child. Clearly, a proper robustness check for women and children's earnings would be very complicated and would require a paper in and of itself. Suffice it to say, then, that including women and children's labour would increase the welfare ratios of the lower deciles of the welfare ratio distribution because they were the poorest families and had the most children available to send into the labour force

[40] Humphries, *Childhood*, pp. 203-7.

(Figure 9). The overall effect on the welfare ratio distribution would be to shift the mean and median upward and decrease income inequality.

The final source of bias in the model is that illegitimacy is not included. This is a necessary assumption because it underpins much of the fertility and mortality figures drawn from Wrigley *et al*., but it also means that female-headed households are underrepresented in the final welfare ratio distributions. There is very little evidence about illegitimate fertility in the preindustrial period because family reconstitution itself focuses on legitimate fertility. However, Laslett and Adair have calculated the ratio of illegitimate births to total births for the early modern period finding great changes in the prevalence of illegitimacy across the centuries. Thus, illegitimacy ratios were quite low from 1650-1700 at 1.6 per cent and had increased substantially by 1750-1800 to 5.29 per cent.[41] It is therefore possible to calculate the number of illegitimate births given the number of legitimate births predicted in the model. These figures are presented in Table 10.

Table 10: Calculation of illegitimate births from predicted legitimate births.

	1650-1700	1750-1800
Illegitimacy Ratio (50-year Average)	1.60%	5.29%
Illegitimate:Legitimate Ratio	1.62%	5.59%
Number of Legitimate Births Predicted	77,716	93,268
Number of Associated Illegitimate Births	1,260	5,212

Sources: Wrigley *et al.*, p. 224.

To account for these illegitimate births, the legitimate model presented above will be reconfigured to produce median welfare ratios for single mothers with illegitimate children, although there are some heroic assumptions involved that are clearly problematic. I will conduct this analysis for the later period, 1750-1800, because illegitimacy ratios were higher in that period, so illegitimacy was more likely to make a difference in the final distribution. In order to predict median welfare ratios for the illegitimate families, I made certain assumptions about the fertility and mortality of illegitimate mothers and children. For fertility, I assumed a parity progression ratio (PPR) of unity at parity zero, 0.5 at parities one and two, 0.25 at parity three, and 0.1 at subsequent parities. These numbers are pure guesses because there is very little evidence about the illegitimate fertility of single mothers. The PPRs are lower for illegitimate fertility because of the social stigma and economic consequences for a mother of having a child out of wedlock.[42] Thus, the low PPRs do not measure subsequent sterility per se but rather women who do not have an additional illegitimate child. These fertility measures yielded a mean of 1.64 children

[41] Wrigley *et al.*, *English Population History*, pp. 219-25.

[42] If illegitimate fertility is held equal to legitimate fertility in the model but the mortality and marriage assumptions described later are held constant, then the median welfare ratio of the illegitimate families falls from 3.37 to 2.92 assuming that mothers of illegitimate children earned 50 per cent of a male building labourer's wage. This difference would still put illegitimate mothers above the median of the legitimate distribution.

born per illegitimate mother but only a median of 1.17 children being supported at one time.

I also assumed that the mortality of illegitimate children was twice the legitimate rate, a common assumption among historical demographers.[43] This meant that levels of infant and childhood mortality were extremely high with 31.9 per cent of infants, 9.3 per cent of one-year-olds, and 5.7 per cent of two-year-olds dying. The assumption about when children left the household was kept the same with a mean age of leaving at 16. The distribution of mothers' ages at the birth of their first child was also changed to reflect earlier ages at first birth relative to the distribution of age of women at marriage, assuming that illegitimate mothers tended to be younger than married women. Again, the age at first birth did not affect fertility in the model but has an influence on maternal mortality risk. Finally, I have attempted to incorporate marriage of illegitimate mothers into the model, though again this is speculative. Illegitimate mothers were given a 5 per cent chance per year of getting married between ages 19 and 32, a 2.5 per cent change between the ages of 15 and 18 and between 33 and 39, and a 1 per cent chance of marriage per year after age 40. These probabilities of getting married were designed to somewhat match the frequency distribution of age at marriage for women in the period 1750-1800.[44]

The family life cycle of an illegitimate family is also different than the legitimate model in one respect. Similar to the legitimate model, the family life cycle for an illegitimate family begins when the mother becomes pregnant and ends with the single mother dying, all of the children dying, or the children leaving the household later in life. However, the illegitimate family life cycle also ended when the mother married. Including the years after remarriage in the model would have an ambiguous effect because the family's income would be much higher despite the fact that more children could be born into the household. Since the purpose of the illegitimacy robustness check is to measure the effect of the underrepresented single mother households in the overall distribution, excluding illegitimate families after the mother married seemed reasonable. 71 per cent of families ended through normal means, the mother or children died or left the household, and 29 per cent of illegitimate family life cycles ended because the mother was married.

Table 11 presents the results of incorporating illegitimacy into the distributions. It is first important to note that the range of possible median illegitimate family welfare ratios was smaller than the range of the legitimate distribution. The median and range of the distribution was also strongly influenced by the wage that illegitimate mothers were assumed to be able to earn. If illegitimate mothers earned 50 per cent of the male wage, as single mothers did in the model, then the median illegitimate welfare ratio was 3.37, a very respectable standard of living indeed, higher than the median of the legitimate distribution. It seems unlikely, however, that mothers of illegitimate children would have been able to earn as much as other women because there was social stigma associated with illegitimacy, the Poor Law was less generous to illegitimate mothers especially after 1834, and the mothers had to care for their children.[45] But how much lower was their income? Table 11 presents

[43] Wrigley *et al.*, *English Population History*, p. 219.
[44] Holding the marriage probability constant at 0.05 rather than changing the probability with the mother's age had a very small influence on the final distribution predicted.
[45] Laslett, 'Introduction', pp. 12-26.

three other income levels, one eighth, one quarter, and three-eighths the male wage, and there are very different affects on the overall distribution depending on which income level is picked. If mothers of illegitimate children earned 37.5 per cent of the male's wage, the effect of adding illegitimate families into the legitimate distribution is negligible. The median actually increased slightly from the legitimate level and income inequality decreased. If the wage rate of illegitimate mothers was 12.5 or 25 per cent of the male wage, then including illegitimate families substantially decreases the medians and means of the combined distribution and increases income inequality.

Table 11: Subsistence welfare ratios for southern English building labourers (1750-1800) controlling for illegitimate families.

	Illegitimacy Adjusted (1750-1800): Percent of Male Wage Earned By Mother				Non-Adjusted (1750-1800)
	12.5	25	37.5	50	Two Parents
Median of Distribution of Predicted Median Illegitimate WRs	0.84	1.68	2.52	3.37	—
Mean of Distribution of Predicted Median Illegitimate WRs	0.87	1.74	2.61	3.47	—
Min of Distribution of Predicted Median Illegitimate WRs	0.32	0.65	0.97	1.30	—
Max of Distribution of Predicted Median Illegitimate WRs	1.15	2.30	3.45	4.60	—
Median of Combined Legitimate and Illegitimate Median WRs	2.36	2.36	2.49	2.62	2.47
Mean of Combined Legitimate and Illegitimate Median WRs	2.41	2.52	2.64	2.76	2.65
Gini Coefficient	0.2281	0.1713	0.1234	0.1512	0.1410

Sources: Simulated results.

Thus, the effect of incorporating illegitimacy into the distribution of median welfare ratios is somewhat ambiguous and depended strongly on the level of earnings of illegitimate mothers. However, the model for predicting the median welfare ratios of illegitimate families is problematic at best, making this robustness check of somewhat limited usefulness.

So what would the net effect of the various robustness checks and biases be? Incorporating illegitimacy is too problematic to come to any definitive conclusion about how it would shape the distribution. Allowing for remarriage shifts the distribution down a bit, but it seems unlikely that this affect would be larger than the upward shift created by incorporating women and children's participation in the labour force and by partially endogenizing the age at which children left the household. Thus, it seems that the median subsistence and respectability welfare ratios presented in Tables 6 and 7 are lower bounds for the actual demography-adjusted figures. Again, this suggests that Allen's original welfare ratios are either close to or slightly below the demography-adjusted figures.

Conclusion

This paper has presented demography-adjusted welfare ratios for two broad reference periods, 1650-1700 and 1750-1800, showing that demography-adjusted welfare ratios are either higher than or match Allen's original real wage estimates. These results are robust to the inclusion of remarriage and illegitimacy in the model, and any women and children's labour force participation would only increase the demography-adjusted figures further. The median family size in terms of consuming units was 2.69 in 1650-1700 and 2.98 in 1750-1800. Family size was much smaller than previous historians have argued for two reasons. First, relatively wide birth spacing ensured that not all children were present in the household at the same time and that the children each reached their peak consumption at different times. Second, mortality of children and adults significantly reduced the number of children born per family and the mouths that needed to be fed by the family. These factors kept family size at a relatively low level.

However, Allen's original real wage series stretch from 1264 to 1914. While these broader time periods cannot be incorporated into the model, it is possible to speculate about how changing fertility and mortality might have affected the distribution from the sixteenth century onwards. Fertility, measured by the net reproduction rate (NRR), was higher from 1550-1650 than from 1650-1700, and infant and childhood mortality was lower.[46] This suggests that family sizes were larger in the period 1550-1650 than in 1650-1700, but not quite as large as in 1750-1800 because fertility was not as high. Thus, Allen's real wages are probably close to the demography adjusted figures until the mid-seventeenth century when decreasing fertility and increasing mortality made family sizes smaller and drove the demography-adjusted welfare ratio above Allen's figure. By the mid-eighteenth century, however, family sizes had again grown because of increasing fertility and declining mortality of children and adults. Allen's real wage was probably again approximately equal to the demography-adjusted welfare ratio. Family sizes were likely at their largest during the first half of the nineteenth century because fertility was unprecedentedly high and mortality was low. Thus, it is possible that the demography-adjusted welfare ratio could have fallen below Allen's real wage figure. In the second half of the nineteenth century, fertility fell to levels similar to those in 1650-1700, but childhood mortality rates also fell substantially.[47] The combined effects of these two processes likely kept family sizes at levels similar to those in 1750-1800, suggesting that Allen's real wages were close to the demography-adjusted welfare ratios.

It is also important to note that the scale of the adjustment for the demographic factors is really quite small. The largest gap between the demography adjusted welfare ratios and Allen's real wages was the difference in the period 1650-1700, but it only represented an 11.77 per cent increase in the welfare ratio. In order to halve the median building labourer welfare ratio in 1750-1800 to 1.225, the median family size would have to equal 6.02 consuming units. Families only reached this level of consumption in 2.55 per cent of the total family years lived 1750-1800. Thus, although adjusting for demography might raise or lower Allen's figures slightly, the demography adjustment is unlikely to change the general trend of the real wages Allen produced. Therefore, scholars wanting to improve upon Allen's method might find querying some of his other assumptions, for instance the constant 250-day work year and the reliance on male wages rather than household income, a more productive way of moving forward.

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[46] Wrigley, *et al.*, *English Population History*, pp. 239, 250-1, 290, 614.
[47] Woods, *Demography*, pp. 6, 253.

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