HUMAN CAPITAL, FERTILITY, AND THE INDUSTRIAL REVOLUTION

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Abstract
The Industrial Revolution and the Demographic Transition are the two great forces that explain the upward march of modern incomes. This paper sets out the empirical realities attempts to unify these events through theories of human capital investment have to meet. The major difficulty is to form an explanation which connects them which can also reconcile the seeming differences in fertility behavior over time and in cross section in the pre-industrial world, the transition period, and the modern world. (JEL: J1, N3, O4)

1. Introduction

Before the Industrial Revolution four features characterized all societies: high fertility rates, little education, the dominance of physical over human capital, and low rates of productivity growth. In modern high-income countries we observe the opposite: low fertility, lots of education, human capital as an important a source of income, and high rates of productivity growth. These conjunctions suggests there must be a connection between the decline of fertility, the rise of human capital, and the onset of modern growth.

We see exactly this transition between society types in Industrial Revolution England. TFP growth rates in the 18th century were less than 0.1% a year, typical of the pre-industrial world. Soon after 1800, rates of productivity growth rose much closer to the modern level of 1% or more per year in a very short period. In England the average women gave birth to nearly five children all the way from the 1540s to the 1890s. Figure 1 shows the gross reproduction rate (GRR), the number of daughters born per woman who lived to 50, by decade. In the England, 10–20% of each female cohort remained celibate. Thus for those who married the average number of births per woman was close to six. The "demographic

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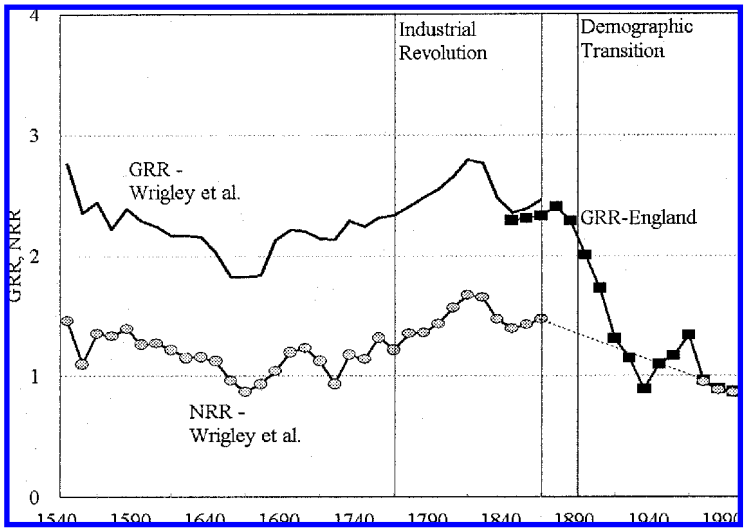

FIGURE 1. English fertility history, 1540–2000. Notes: GRR = Gross reproduction rate. NRR = Net reproduction rate. Sources: Wrigley et al. (1997), p. 614. Office of National Statistics, UK.

transition" to modern fertility rates began only in the 1890s. By 2000, English women gave birth on average to less than two children.

Since pre-industrial child mortality rates were high, however, the Net Reproduction Rate (NRR), the number of daughters per woman who lived to childbearing years themselves, fell much less. Figure 1 shows the NRR for England. Normally the NRR would be a small amount above one in the Malthusian era. England in 1540–1800 thus had an unusually high NRR for a pre-industrial society. Note that the GRR and NRR both rose in the course of the Industrial Revolution, whose onset is traditionally taken as in the 1760s.

Education levels did increase in England over the Industrial Revolution years. Figure 2 shows a measure of very basic literacy, the fraction of men and women able to sign their names on witness statements or marriage registers. Comparing Figure 2 to Figure 1, there is little or no connection between changes in literacy rates and changes in fertility. Most of the fertility transition occurred after the attainment of near universal literacy.

2. Income and Human Capital

What triggered the switch to the modern equilibrium with smaller numbers of children and large amounts of human capital? The first possibility is the general rise of incomes. This would imply the demographic transition was merely an echo

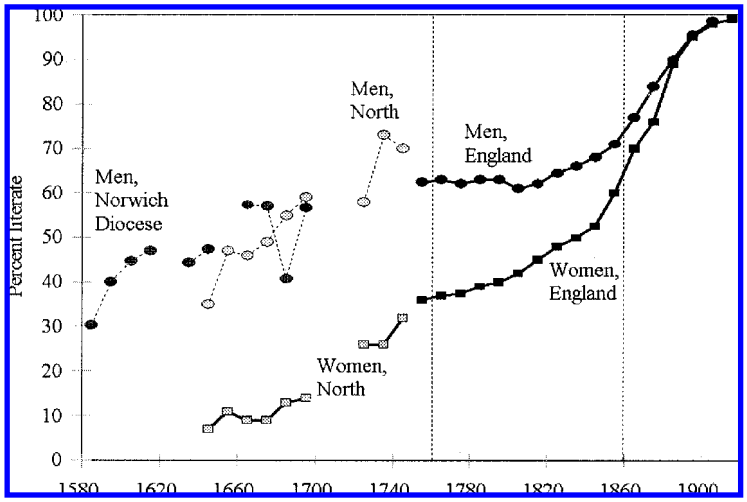

FIGURE 2. Literacy in England, 1580–1920. Source: See Clark (2004).

of the Industrial Revolution. Figure 3, for example, shows the hourly real wage of building workers in England from 1200 to 2000. Real income gains were actually modest in the classic Industrial Revolution period. Only after the 1860s did real wages begin to rise rapidly. Only after the 1860s did fertility decline substantially. In the modern world there is a strong negative fertility-income relationship across countries.

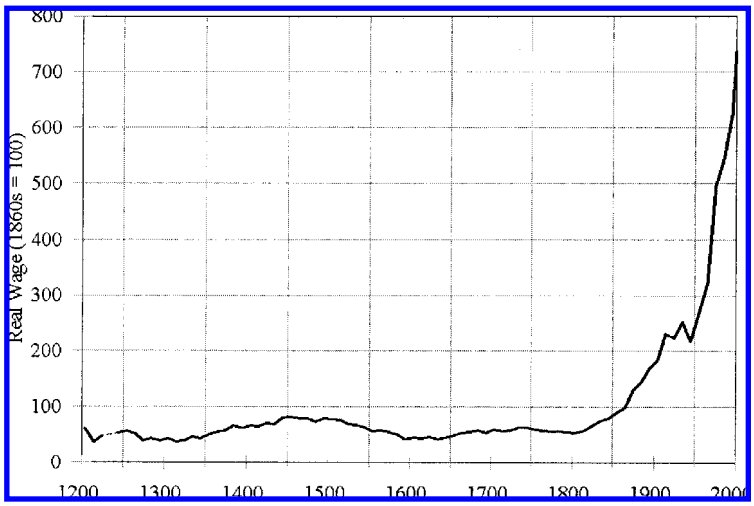

FIGURE 3. Real day wages of building workers (1860–1869 = 100). Source: Clark (2004).

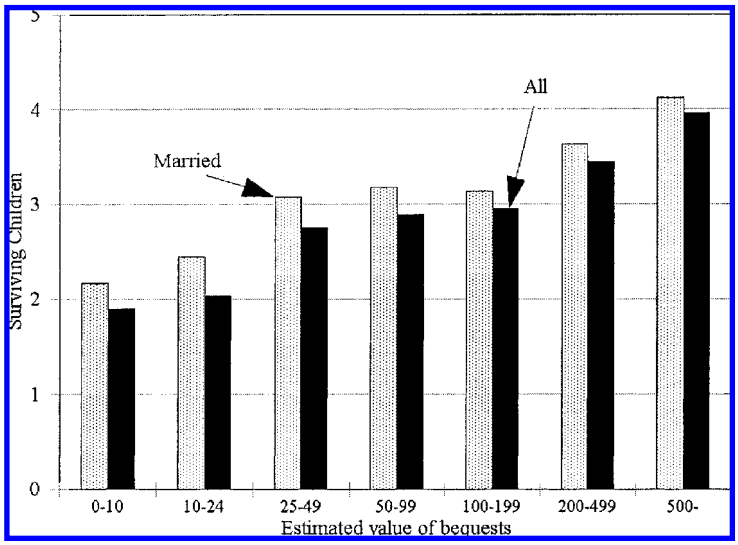

FIGURE 4. Surviving children by assets of Testator, England, 1585–1636. Note: Assets in £. Source: Clark and Hamilton (2004).

We also see in late 19th century England during the demographic transition a negative association between higher social class (a proxy for income) and numbers of children. The estimated of numbers of children present in households by the occupation of the male household head is lower for the professional classes than for laborers.

The problem with explaining the fertility transition through income is that all plausible models of population regulation for the pre-industrial world depend on a positive association between NRR and income for some range of incomes. Information on fertility compared to income is rare for the pre-industrial world. But Clark and Hamilton (2004) infer the connection in between fertility and income circa 1600 from wills of male testators in pre-industrial England. The numbers of surviving children and the total value of bequests can be estimated for each testator. Figure 4 shows the average numbers of surviving children per testator for each bequest class. A man bequesting less than £10 would typically leave two children, while one bequesting more than £500, four children. Assets, undoubtedly correlated with income, predict survivors. Thus in pre-industrial England there was a positive association between income and net fertility over a wide range of incomes.

This positive association between fertility and income seemingly becomes negative in the period of the demographic transition. But in modern high income low fertility societies there seems to be no association between income and fertility. A recent study of female fertility found on average no association between

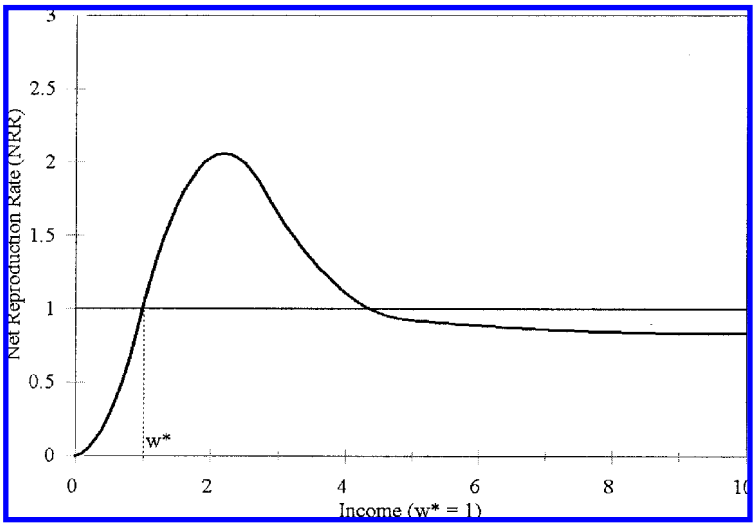

FIGURE 5. The fertility income relationship. Note: The subsistence level of income is portrayed as $w^* = 1$.

household income and fertility, measured as the numbers of children present in the households of married women ages 30–42, for both 1980 and 2000, for the six countries Canada, Finland, Germany, Sweden, the United Kingdom and the United States (Dickmann 2003, Table 2). This suggests that the income-fertility relationship within societies changed dramatically over time. But note that in England around 1900, the only period with a clear negative relationship, the fertility data is for gross fertility. Given high child mortality rates in these years (evident in Figure 1) it may be that in all the cross sections there is no decline of net fertility with income.

Thus the relationship between net fertility and income as we move from the pre-industrial to the modern era seems as portrayed in Figure 5. The very different behavior of the link between income and fertility in cross-section in the pre-industrial era, the era of the fertility transition, and recent years makes constructing a link between fertility and income challenging.

One basic idea, implemented in a number of ways, is the following. Suppose we were to posit the utility of the parents in goods and children is a function of the form

$$V_t = c_t^{\alpha} n_t^{\beta}, \tag{1}$$

where c is parental consumption and n is the number of children. If we posit a fixed parental time cost per child, then fertility will be independent of income if wages are the only source of income. To get parents choosing less children at

higher incomes we can elaborate equation (1) into a utility function where parents also care about the utility of their children,

$$V_t = c_t^{\alpha} n_t^{\beta} V_{t+1}(y_{t+1})^{y}, \tag{2}$$

y_{t+1} is the income of the children. Suppose also that the income of the children depends on the investment in human capital, so that

$$y_{t+1} = G(H_{t+1}), \tag{3}$$

where H_{t+1} is investment in human capital per child. If $G(H) > 0$ then parents may choose to spend extra income, not in more children, but in higher quality children. We can then explain the negative income-fertility relationship in the modern world by positing an increased dependence of child income on human capital, and hence a preference for fewer, higher quality, children.

But in this case, why does fertility increase with income in the pre-industrial world? Authors who have addressed this have concentrated on explaining the association for incomes close to subsistence level. Thus Galor and Weil (2000), and Galor and Moav (2002) assume a minimum consumption level that parents have to achieve before they produce children. Lucas (2002) assumes children require a minimum consumption transfer.

We see in Figure 4, however, that very high income families in the pre-industrial world, those beyond any conceivable peak in the fertility-income curve shown in Figure 5, did not display any reduction in Gross or in Net Fertility Rates. In Figure 4, for example, the richest testators, those with net fertility double those of the poorest testators, had average estimated assets of more than £900. This means their asset income alone was about triple the wage income of an artisan. They were certainly wealthy even relative to agricultural laborers in 1911. Yet by 1911 the gross fertilities of all groups in England had begun to decline.

One way of reconciling the different behavior of high income families in the pre-industrial world and the modern world would be to posit that high incomes in the past came predominantly from ownership of nonhuman assets, while modern high incomes come predominantly from human capital. But it is an unresolved empirical question whether in cross section fertility in both the pre-industrial and modern world correlates differently with income for those like the gentry who relied entirely on asset income as opposed to skilled workers such as attorneys and merchants who relied mostly on human capital.

A second way to get a positive association of income and fertility before the Industrial Revolution is to assume that human capital is not productive in pre-industrial society, so that the utility function of the family is some variant of equation (1) before the Industrial Revolution. If we also assume that children have a fixed production cost, independent of parental consumption, then we would

get a positive association of income and fertility. The empirical realism of this assumption is again untested.

A second problem with wage income as the driver of fertility is that it makes gains in human capital a consequence of the Industrial Revolution and not a cause. We would thus be left trying to explain the productivity upsurge of the Industrial Revolution by other means. The third problem is that we cannot explain the evidence of rising human capital in the years before the Industrial Revolution as a consequence of income gains. It leaves unexplained the gains in human capital that clearly preceded income gains in the Industrial Revolution.

3. Human Capital Externalities

Another mechanism that might explain both the rise in human capital, the decline in fertility, and the Industrial Revolution, would be an increase in the premium paid for human capital in the Industrial Revolution era. Suppose, for example, there is a positive externality from human capital. The wage gains from individual's investments in human capital depended positively on average investments in human capital. That is,

$$y_{t+1} = G(H_{t+1}, \overline{H}), \tag{4}$$

where $\overline{H}$ is the average level of human capital. Now there is possibly a low-level pre-industrial equilibrium where earnings and the benefits from investing in human capital were both low.

In most settled pre-industrial economies the bulk of labor demand was for agricultural work where levels of human capital were low. The typical agricultural laborer in the nineteenth century in England, for example, achieved their maximum wage by age 20. Earnings were flat after this until they declined after age 60 (Burnette 1999). In such an economy, it is argued, parents would favor quantity over "quality" in children. This idea is expressed in Becker, Murphy, and Tamura (1990), and also in Galor and Weil (2000).

However, for this explanation is to be compatible with the individual incentives, the gain to children's earnings from investment in their human capital before the Industrial Revolution has to be low. In fact we find in England, and in a variety of other pre-industrial economies, that rewards to human capital were higher than the modern economy! We have, for example, the skill premium in the building industry: the ratio of the wages of craftsmen to building laborers (Clark 2004; van Zanden 2004). Figure 6 shows the wages of craftsmen relative to laborers by decade from 1200.

The period 1600–1900, when literacy rates increased markedly, was one where the skill premium was constant. After 1900 when fertility rates fell it was in a labor market where the premium for skills also declining markedly. Thus

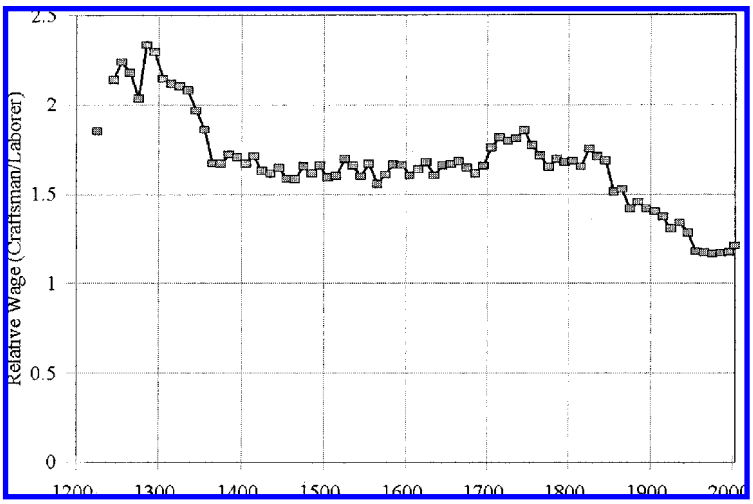

FIGURE 6. The skill premium for building workers. Source: Clark (2004).

the general result seems to be that gross fertility is highest where the premium for skills in the labor market is greatest. This strongly suggests that a demand interpretation of fertility decline, on its own, will not work either in England, or as a general explanation of the fertility transition. The flatness of the skill premium shown in Figure 6 could, however, be the product of simultaneous demand and supply shifts.

4. The Supply of Human Capital

Since the expansion of human capital first occurred when the return to human capital was constant the gains of the Industrial Revolution era had to involve significant supply shifts. Galor and Moav (2002) posit that the supply shift was created by Darwinian competition in the pre-industrial economy between families with different tastes for child "quality." In the Malthusian world each family can have a NRR only slightly above 1. But "high quality" families do better. High quality types produce offspring who, because of their greater human capital and hence higher incomes, can afford to have more children. Thus when incomes are close to subsistence they out-produce the "low quality" types.

It is correct that in all pre-industrial societies, because of the Malthusian constraints on population, different parenting characteristics potentially had differential reproductive success. It is also correct that in societies like England selection was largely through economic competition. Here, in contrast to hunter gatherer groups and many settled agrarian societies, the major source of death

was not violence, but disease. From 1200 to 1800 typically less than 2% of male deaths were caused by violence in England. Males in England gained resources by economic competition. And these resources, as Figure 4 shows, were associated with higher net fertility rates.

But if this selection process was operating, it would affect more than just the preference for quality as opposed to quality in children. In Galor and Moav's formulation, for example, "high quality" types dominate because of the minimum consumption constraint. The positive income-fertility association well above subsistence incomes is not predicted within their model which looks at only human capital. We can potentially explain this association by assuming high pre-industrial incomes derived mainly from physical assets. But then we have introduced a complication that the Galor and Moav model does not contemplate. Now selection in the pre-industrial world would also be for characteristics such as differences in preferences for parental as opposed to offspring consumption.

Interestingly England was a society which by 1750 had a number of characteristics that distinguished it from most pre-industrial societies. Included were very high levels of labor input to productive activities, and a low rate of time preference which resulted in low interest rates (Clark 2005). Given that prior to the Industrial Revolution England experienced 600 years where reproductive success was dictated largely by economic competition plausibly these characteristics were all the result of some wider Darwinian competition over reproductive success.

All this can explain the upward drift in the amounts of human capital long before the Industrial Revolution evident in Figure 3. Through interactions and externalities it can also perhaps explain the Industrial Revolution itself. But we are left with the conundrum of declining net fertility post 1890. If the economic system prior to the Industrial Revolution selected those with a tendency to use higher incomes to achieve greater net fertility, why did all this change in the 1890s? Two prominent candidates are the changing roles of human and physical capital, and changes in the economic and legal status of women.

5. The Earnings and Status of Women

Plausibly the Industrial Revolution increased the relative earnings of women. Most labor in the pre-industrial world involved mainly the supply of power through human muscles. Men have an advantage here. Women's earnings in pre-industrial agriculture in England were thus typically only 40–60% those of men (Clark 2003). But in the modern world workers supply almost exclusively dexterity and cognitive skills, where men have no advantage. The average earnings of women have greatly improved relative to those of men in the last 50 years.

If women, as a consequence of their low relative earnings before the Industrial Revolution, did most child rearing, then the rise in relative female earnings could explain declining modern fertility. Galor and Weil (1996) develops such a model formally. The puzzle for historians has been, however, that female labor force participation seems to have declined in countries such as England when real wages began to rise in the late 19th century. Thus the 1851 census in England ascribes an occupation to 25% of married women. By 1901 the census categorizes only 13% of married women as employed by 1931 a mere 10%. Marital fertility declines just when married women are withdrawing from the labor force, in part because the Industrial Revolution moved most industrial occupations out of the domestic setting into factories. Goldin (1990) reports a similar effect for the United States.

Further, in England in 1851 female participation in different regions is not well explained by relative wages. In the northern industrializing areas women constituted more than 30% of the hired farm labor force in some counties, while in the more rural south women were less than 5% of hired farm labor in many countries (Clark 2003). Yet the wages of female farm workers were lower relative to male farm wages in the north. High labor force participation in the Industrializing north reflected a shift in female labor supply, not changes in demand.

A striking feature of Figure 2, however, is the coincidence of the rise in the literacy of women in England and the onset of the demographic transition. Suppose we were to take literacy rates for women as an index of the relative status and power of women in household decision making. Also assume that the numbers of children desired by women was always significantly less than for men in a world where early childcare was the province of women only. Finally assume the rising relative status of women, like, female literacy, spread down through the social classes from the upper classes first.

These assumptions could explain why net fertility falls after the late nineteenth century even though in cross-section in the sixteenth century and in 2000 there is either a positive connection between income and net fertility or no connection. They could also explain why the demographic transition appeared first in the higher socioeconomic status groups, so that net fertility was negatively related to income in the transition period.

6. Conclusion

The Industrial Revolution and the Demographic Transition are the two great forces that explain the upward march of modern incomes. So far they have stood as independent phenomena, the Industrial Revolution not leading in England to any decline in fertility till over 100 years later. Our instincts suggest that there is some underlying connection between these events. The difficulty is to connect

them in a way also reconciles the differences in fertility behavior in cross-section in the pre-industrial world, the transition period, and the modern world.

References

Becker, Gary, Kevin Murphy, and Robert Tamura (1990). "Human Capital, Fertility and Economic Growth." *Journal of Political Economy*, 98, S12–37.

Burnette, Joyce (1999). "Wage Profiles of Agricultural Laborers in Early Nineteenth Century Britain." Working paper, Wabash College.

Clark, Gregory (2003). "Agricultural Labor" and "Agricultural Wages." In *The Oxford Encyclopedia of Economic History* Vol. 1, edited by Joel Mokyr. Oxford University Press.

Clark, Gregory (2004). "The Condition of the Working Class in England, 1209–2003." Working paper, UC-Davis.

Clark, Gregory (2005). *The Conquest of Nature: An Economic History of the World*. Princeton University Press, forthcoming.

Clark, Gregory and Gillian Hamilton (2004). "Was Pre-Industrial Society Malthusian? Tests from England and New France." Working paper, UC-Davis.

Dickmann, Nicole (2003). "Fertility and Family Income on the Move: An International Comparison over Twenty Years." Working paper, Maxwell School, Syracuse University.

Galor, Oded and Omer Moav (2002). "Natural Selection and the Origin of Economic Growth." *Quarterly Journal of Economics*, *117*, 1133–1192.

Galor, Oded and David N. Weil (1996). "The Gender Gap, Fertility and Growth." *American Economic Review*, 86, 374–387.

Galor, Oded and David N. Weil (2000). "Population, Technology and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond." *American Economic Review*, 90, 806–828.

Goldin, Claudia (1990). *Understanding the Gender Gap: An Economic History of American Women*. Oxford University Press.

Lucas, Robert E. (2002). "The Industrial Revolution: Past and Future" in *Lectures on Economic Growth*. Harvard University Press.

Van Zanden, Jan Luiten (2004). "The European Skill Premium in International Comparative Perspective, 1200–1950." Working paper, University of Utrecht.

Wrigley E. Anthony, Ros S. Davies, James E. Oeppen, and Roger S. Schofield (1997). *English Population History from Family Reconstitution*, 1580–1837. Cambridge University Press.

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