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POPULATION AND ECONOMIC GROWTH

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I suspect that the disagreement that occasionally arises among economists or between economists and demographers concerning population growth theory and "the population problem" has two causes. One is failure of communication, resulting from unclear statement of assumptions. The other is the persistence in our minds of Malthusian conclusions, even though we have forgotten the assumptions on which they are based.

It should be possible to eliminate the sources of disagreement. In this paper I distinguish three cases of population growth which encompass major aspects of the world's population experience; present an analytical model that seems consistent with all three; and compare its relevance to reality with that of the Malthusian model.¹ Section I

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1. I do not deal with questions of optimum population size or with factor proportions in a static setting, or with questions of cyclical change in population growth rates.

distinguishes the three cases. Section II discusses relevant historical data, and Section III presents the basic model. Section IV and an algebraic appendix elaborate it to make it applicable to post-World War II experience. Section V contrasts it with the Malthusian model.

I. THREE CASES OF POPULATION INCREASE

First consider population growth in low income (peasant) societies. In such societies, crude birth rates are virtually everywhere above forty per thousand.² Although higher birth rates are biologically possible, this is close to the practical maximum. Historically, death rates have been almost as high. Where population growth occurs in such societies, it occurs because death rates fall. Two causes of falling death rates may be distinguished fairly sharply.

One is the introduction of modern public health measures and other preventive medical measures. I shall term the resulting fall in death rates exogenous. The fall in death rates is followed only after a lag of undetermined but considerable length by a fall in birth rates. In the interval population increases, or, if it was increasing

2. In Western Europe, before the Industrial Revolution, late marriages were common and crude birth rates were only about 35 per thousand. This difference may have predictive significance. I discuss it briefly below, note 32, page 28.

previously, the rate of population growth rises.

The second cause is a rise in per capita income.³ Historically, there have been two major causes of rise in aggregate income, the opening up of new territories and technological progress. The former merely enlarges the scale of the economy, and permits it to support more persons, without directly affecting per capita income.⁴ Technological progress, however, in the general case directly increases per capita income. People live more healthfully, the death rate falls, and population grows or the rate of population growth increases. If it increases until it equals the rate of growth in aggregate income, per capita income of course ceases to rise.

Life expectancy in Western societies is consistent with a death rate of fourteen or fifteen per thousand even with a stabilized age distribution of the population; and crude death rates of four or five per thousand are possible with population concentrated in the lower

3. Of course the availability of public health and other preventive measures constitutes a rise in income. The reference here is to a rise in general purchasing power.

4. The filling of "empty lands" was conspicuous in Western Europe during the Middle Ages and more recently in the history of the United States, Canada, Australia, and New Zealand, and, after 1650, with the introduction of new crops, in China. In all of the recent cases except China, continuing technological progress was of course occurring at the same time. Even where there is no progress in known technology, there may of course be economies of scale which increase productivity. I shall not discuss their relation to population. The reader will be able to apply the argument of Section III.

age groups, as is true for some time after death rates decline. With birth rates between 40 and 45 per thousand, a decline in death rates to Western levels could bring population growth at the rate of 35 per thousand, or 3.5 percent, per year. This maximum practical rate of population increase is of importance for population theory.⁵

Distinguishing between population growth due to exogenous and to income-induced declines in death rates is analytically important. While the first is obviously a problem of great practical concern, I shall assert that the second has in the past been of no realistic importance. This is true in the sense that income-induced population growth has nowhere prevented even a moderate rate of rise in the aggregate income of an economy from bringing continuing rise in per capita income.⁶ This is no coincidence. A reasonable interpretation of history suggests a mechanism at work which guaranteed that it would not do so. The relevant functions are changing, and whether the same guarantee will hold good in the future is a complex question. I discuss it in Section III.

5. Birth rates of 50 or 55 per thousand are biologically possible, and have prevailed in limited areas for periods of moderate length. Thus a rate of population growth much higher than 3.5 percent per year is conceivable. However, this rate may be taken as a practical maximum.

6. Of course income-induced population growth may prevent the rise in per capita income from being as fast as it otherwise would be.

The recent spurt in population growth in the West constitutes the third case I shall discuss. Since World War II, population growth has accelerated in the United States and Western Europe because of a new phenomenon, a rise in birth rates. In the United States and at least some Western European countries, this rise is not simply the concentration in the postwar period of births postponed from depression and war, for it is characterized by the^{pro}creation of a far larger number of third and fourth children than was previously customary. Further, in some countries it is still continuing. This case of population growth stands at one side of the historical trends that alarmed Malthus and many subsequent analysts. I shall discuss it only to the extent of suggesting possible alternative causes, and asking whether any of them is inconsistent with my basic model.

II. HISTORICAL POPULATION GROWTH: THE DATA

The historical distinction between exogenous and induced population growth is fairly clear. Exogenous declines in death rates have attracted attention mainly since World War II. Through technical assistance from abroad, death rates in a considerable number of peasant countries have fallen drastically, most abruptly of all in Ceylon. Birth rates have remained high, and as a result in recent years population growth has been approximately three percent per year,

or more, in Ceylon, Malaya, Mexico, Venezuela, Ecuador, and several Central American countries and Caribbean areas, and well above two percent in a number of other countries. Because of the recency of the declines in death rates, the ^{minimum} length of the lag before birth rates fall is unknown, except that it is probably more than a decade.⁷ In the historical cases of less spectacular fall in death rates, the lag has been as long as several generations. If it should now be a generation or longer, the effect on living levels in low-income countries where rapid technological progress is not occurring may be catastrophic.

It is not so widely observed that the slower but increased rate of population growth in a number of peasant countries over a longer period has been due to the same mechanism. From the beginning of the Christian era to 1650, the average rate of growth of world population was in the neighborhood of 1/20 of one percent per year. It then began to rise, first in Western Europe, but during the last half of the nineteenth century ⁱⁿ the peasant societies, which were then colonial. The modal rate in peasant societies between 1900 and World War II was probably between .5 and one percent per year. While precise data are

7. The crude death rate in Ceylon, as recorded in the United Nations Demographic Yearbook, fell from 19.8 in 1946 to 14.0 in 1947, and continued down to below ten in 1956. The crude birth rate, which remained between 38.4 and 39.8 from 1946 to 1953, fell from 38.7 in 1953 to 35.7 in 1954, giving possible hope of a spectacularly short lag. But in 1955 it was 37.3 and in 1956 36.4, thus quenching the hope of a quick downward trend. Age-specific birth and death rates for these recent years are not available.

of course not available, historical evidence indicates rather clearly that the level of per capita income in such societies had not risen before the rise in the population growth rate. There is also historical evidence that the increased rate of population growth has resulted specifically from gradual introduction of improved medical and health practices under colonial administrations.⁸ Because some observers point to this population rise in peasant societies as evidence that a rise in per capita income may be swamped by population growth, it is worth while to assert specifically that the rise in aggregate income in peasant societies within the century before World War II was predominately a result, not a cause, of population growth. The forces at work in these areas tending to increase the income of the mass of the population were extremely weak. Colonial administrations did not induce continuing technological progress in the areas they controlled.

Continuing technological progress begins when an adequate base of scientific-technical knowledge is available (a condition now everywhere fulfilled), and when socio-psychological changes have occurred such that a sufficient number of the individuals of the society devote their energies to problems of technological innovation. Certain con-

8. In China, by way of exception, population growth presumably resulted primarily from introduction from abroad of the sweet potato, peanuts, and early-ripening rice, which permitted the settling of large land areas that would not previously support population.

ditions of capital supply are also necessary; they may be independent conditions or may follow if the socio-psychological conditions exist.⁹ During the nineteenth and twentieth centuries, these conditions came to exist in twenty-some countries of the world. Continuing technological progress began, and brought (an accelerated rate of) increase in aggregate output. As this increase got under way, per capita income steadily rose. The death rate gradually declined. The rise in income permitted maintenance of larger and larger families, if desired. If the simple Malthusian model of population behavior¹⁰ is realistic, in each of these countries, as per capita income rose, at some point population growth should have reached a rate equal to the rate of growth in aggregate output, thus checking the rise in per capita income. Or, alternatively, if the rate of rise in aggregate output was so fast that it exceeded the realistic maximum biological rate of population growth--say 3.5 percent per year--¹¹ population growth should

9. Some economists believe that it begins when certain economic barriers, bottlenecks, or vicious circles are broken, and ignore the social and psychological factors. This difference of opinion concerning the causal factors is not important for the present purpose, but it is important to note that technological progress, not merely capital formation, is in point.

The hypothesis that socio-psychological changes are of central importance does not rule out the necessity of political change. This may in some cases be necessary in order that the new groups can be free to act.

10. I use the term "simple Malthusian model" loosely here. For a statement of the essential elements of the Malthusian model, see Section V.

11. See note 5, above.

have reached that rate. The historical facts of income and population growth will test the thesis.

I shall examine the facts only in countries in which a moderate or rapid rate of rise in aggregate output (1.5 percent per year or more)¹² began before the end of the nineteenth century, since where it began only in the twentieth century it is possible that population growth has not yet reached its peak. There are seventeen such countries, and only seventeen. Nowhere else in the world could population growth have checked rise in per capita income, because nowhere else (before 1900) did an accelerated rate of increase in aggregate output occur.¹³ Professor Kuznets in a recent compilation presents data concerning growth of output and population for thirteen of these seventeen.¹⁴

12. I include Ireland even though its rate of increase in output was slightly lower.

13. Obviously, population increase could not have prevented a rapid rise in aggregate output; it is favorable.

14. Simon Kuznets, Quantitative Aspects of the Economic Growth of Nations: I. Levels and Variability of Rates of Growth, being Vol. V, No. 1 (October 1956) of Economic Development and Cultural Change. For the United Kingdom and the United States, the period covered by Kuznets' data may not be the periods of most rapid growth in output. More rapid growth may have occurred earlier, i.e. before 1860.

Table 1 presents the data. While data for the growth of output in the nineteenth century are not available for the other four countries,¹⁵ it is clear from general historical comments about those countries that the course of events in them paralleled that in the other thirteen. In each country, the death rate fell as nutrition, health care, etc. improved. The rate of population growth would have approached the biological maximum if birth rates had simply remained at their previous level as income rose. What happened?

1. In no country except the United States and Canada--where vast empty lands cried out to be filled--did rise in income stimulate population growth remotely approaching that which Malthusian theory indicates rising income should induce. In no case except those of "empty lands" did the rate of population growth exceed 17.5 percent per decade even for a single decade.¹⁶ The median peak decade rate among the thirteen countries is 12.5 percent. Over the fifty years of fastest growth, the median is much lower.

15. Belgium, the Netherlands, Norway, and New Zealand. For all but Belgium Kuznets presents data for the twentieth century.

In the twentieth century, rapid growth began in a number of other countries, for example, Czechoslovakia, Poland, Mexico, Brazil, Colombia, and perhaps also Hungary, Turkey, Argentina, and Chile. Some other Latin American countries, and possibly one or two elsewhere, might be added.

16. In Australia, New Zealand, the United States, and Canada, during an early pre-industrial period of filling empty lands, population growth reached higher rates than those shown in Table 1, but this growth is not relevant to the present argument.

Table 1

Average Percentage Change per Decade, Population and National Product, Constant Prices, Thirteen Developing Countries, Two Periods, and Maximum Decade Percentage Change in Population.

(1) Country	(2) Period ^a	(3) Percentage Change per Decade National Product	(4) Percentage Change per Decade Population	(5) Decade of Highest dP/dt Approximate Dates ^a	(6) Percentage Change
Australia	1886/94-1945/54	26 ^b	17 ^b	1869-1879	12.4
Canada	a)1870/79-1950/54 b)1870/79-1905/14	41.3 47.1	18.3 17.8	1899-1909	30.2
Denmark	a)1870/78-1950/54 b)1870/78-1904/13	30.1 32.7	11.5 11.3	1913-1923	17.5
France	a)1841/50-1949/53 b)1841/50-1901/10	15.3 18.6	1.3 1.9	1855-1865	4.7
Germany	a)1860/69-1950/54 b)1860/69-1905/14	27.4 35.6	10.1 11.5	1894-1904	15.2
Ireland- Eire	a)1860/69-1949/53 b)1860/69-1904/13	12.8 11.6	-3.5 -5.4	1938-1948	0.0
Italy	a)1862/68-1950/54 b)1862/68-1904/13	18.0 15.7	6.9 7.0	1923-1933	8.0
Japan	a)1878/87-1950/54 b)1878/87-1903/12	42.3 49.2	12.7 11.6	1937-1947	14.7
Sweden	a)1861/68-1950/54 b)1861/68-1904/13	36.0	6.6	1938-1948	12.5
Switzer- land	a)1890/99-1939/48	21 ^b	7 ^b	1894-1913	10.5 ^c
Russia- U.S.S.R	a)1870 - 1954 b)1870 - 1913	31.0 27.7	13.4 15.7	1870-1885	15.3 ^d
United Kingdom	a)1860/69-1949/53 b)1860/69-1905/14	21.5 25.0	8.0 11.1	1869-1879	12.4
United States	a)1860/69-1949/53 b)1860/69-1905/14	21.5 25.0	8.0 11.1	1873-1883	24.7

Source: Cols. 5 and 6, Kuznets, loc. cit., Appendix Tables 1-5, 7, 9, 10, 13-15, 17-18; cols. 2-4, *ibid.*, Table 6, except Australia and Switzerland, which were computed from Appendix Tables 18 and 5, respectively.

(For notes, see next page.)

Table 1 (continued)

a. Generally, Kuznets presents data for overlapping decades. His population data are shown as for intervals from one overlapping decade to another. The dates given in col. 5 are the fifth years of the decades he cites.

b. The decade rate from the first to the last period covered. Other percentages in these columns are trend line rates.

c. The decade rate for the 20-year period.

d. The decade rate for the 16-year period.

2. In no country did the rate of population growth approach the rate of growth in aggregate output. In fact, in none except the United States did the peak rate of population growth for a single decade approach the average rate of growth in output for the entire fifty- to one hundred-year period covered.

3. In England, there is evidence concerning the rate of change in aggregate income during the century before the period of most rapid growth. The evidence indicates that rise in aggregate income began slowly, then accelerated only gradually. Various studies give conflicting evidence about the timing of rise in output within the eighteenth century, but all indicate that over the century as a whole, output rose. Phyllis Deane's estimates indicate an average rate of growth for the century (which she thinks was concentrated in the first half of the century) of about 15 percent per decade. Population growth

failed to keep pace even with this moderate rate; it rose by about six per cent per decade.¹⁷ Population growth did not match that in output even during an early period of a slow rate of growth from a low level of income.

The evidence thus indicates not merely that the expected "Malthusian" result did not occur generally, but that it did not occur anywhere. Instead, birth rates followed death rates downward long before a maximum rate of population increase had been reached, and both continued downward until they reached secular minima.¹⁸

These facts raise the important question whether technological progress is apt to bring such favorable results wherever it begins in the future. The uniformity of the past result suggests that there was a mechanism at work which necessarily caused it. In order to know whether we may appropriately extrapolate in time, it is worth while to inquire what that mechanism may have been.

17. See two articles by Phyllis Deane in Economic Development and Cultural Change: "The Implications of Early National Income Estimates For the Measurement of Long-Term Economic Growth in the United Kingdom," IV (November 1955), 3-38, and "The Industrial Revolution and Economic Growth: The Evidence of Early British National Income Estimates," V (January 1957), 159-174. Concerning other estimates of income or production, see T. S. Ashton, An Economic History of England: The Eighteenth Century (Barnes and Noble, New York, 1955), and sources cited by him.

18. See the sources cited by Kuznets, loc. cit.; or for a general description of the trend see any standard demographic discussion, such as R. R. Kuczynski, The Balance of Births and Deaths, 2 vols., New York, The MacMillan Co., 1928-1931.

III. AN ANALYTICAL MODEL

Figure 1 portrays the relevant model. Aggregate income is indicated by Y , population by P , and a dotted symbol represents a first derivative with respect to time. Thus \dot{Y} is the absolute increment in aggregate income per time period, and \dot{Y}/Y is the percentage, i.e., proportional, change per time period. Income per capita (Y/P , or y) is shown on the horizontal axis, and rates \dot{Y}/Y and \dot{P}/P (abstract numbers) on the vertical. ¹⁹ For convenience, \dot{Y}/Y is referred to as v , and \dot{P}/P as r .

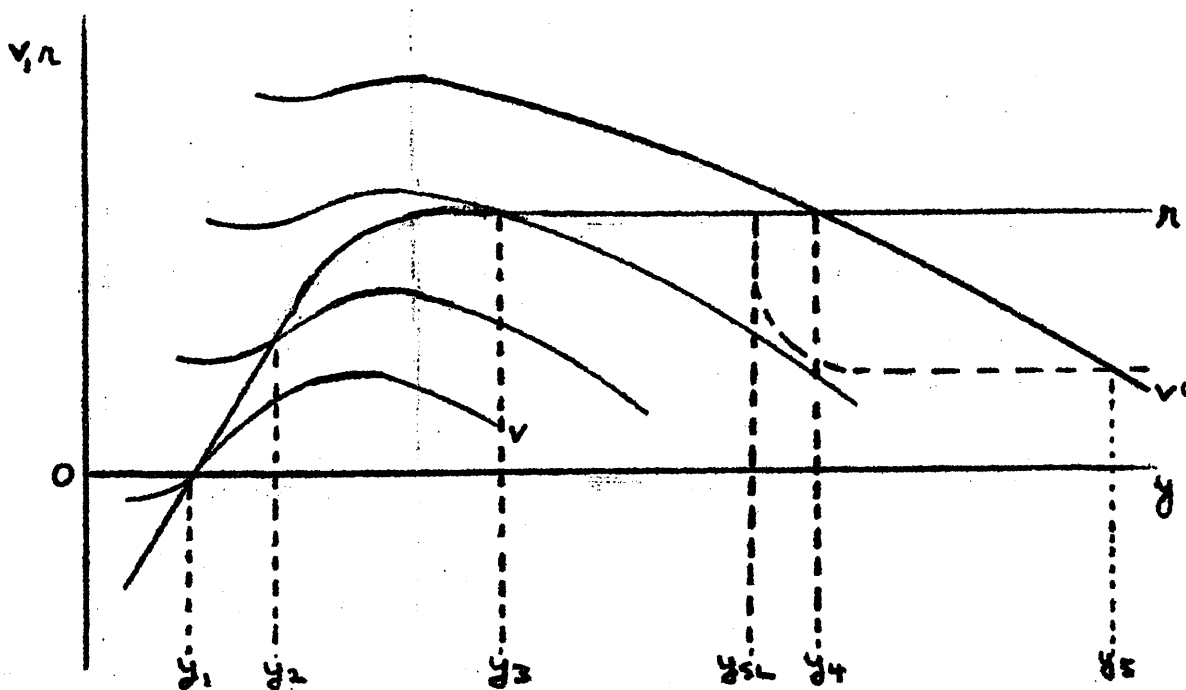


Figure 1. The Simple "Malthusian" Model

19. The axes and \dot{P}/P or r curve are those of Figure 3a in R. R. Nelson, "A Theory of the Low-Level Equilibrium Trap in Underdeveloped Countries," American Economic Review, XLVI (December 1956),

Full employment is assumed, and for simplicity the level of employment is assumed to bear a constant ratio to population. Output is a function of capital and labor inputs only. "Land" will be introduced later. A conventional production function and constant returns to scale²⁰ are assumed. Each \dot{Y}/Y or v function reflects a constant state of the arts. Movement along a v function from a lower to a higher y results solely from an increase in the ratio of capital inputs (C) to labor inputs (P). An upward shift of the function results from technological progress or an upward shift in the function relating saving (S) to income or both.

The \dot{P}/P or r curve is assumed to rise with rising y until it reaches a maximum set by biological limitations (the practical maximum rather than the highest conceivable level), after which it remains horizontal. The shape of the v curve depends on the operation of the law of variable proportions (in relation to variations in the C/P ratio), the rate of saving at different per capita income levels, the rate of population growth at different per capita income levels, and

894-98, which seems to me the sharpest delineation in print of the Malthusian model. For two other articles that use the graphic device of rates on one axis to deal elegantly with problems of economic growth, see R. M. Solow, "A Contribution to the Theory of Economic Growth," Quarterly Journal of Economics, LIX (February, 1956), 65-94, and Trevor Swan, "Economic Growth and Capital Formation," Economic Record, November 1956, 334-61.

20. A different assumption concerning returns to scale slightly complicates the statement of the argument without affecting the conclusions.

returns to scale (here assumed constant). The specific shape assumed does not affect the argument here, so long as the curve intersects the r curve from above, as in Figure 1.²¹ It must intersect thus to reflect the Malthusian assumption of a tendency for population increase to check the rise in per capita income. At any intersection of the two curves y is constant, since $v = r$. If the v curve intersects from

21. The more steeply the curve rises in the area to the right of its intersection with the r curve, the less the upward shift necessary for it to arch above the r curve, eliminating the low-income-level intersection (intersecting far to the right as the v curve turns down again), and thus escaping the Malthusian low-income-level-equilibrium trap. Similarly, if the v curve arches upward sufficiently, at the right of its intersection with the r curve, it may intersect the r curve from below, creating an unstable equilibrium that will permit escape from the low-level-equilibrium trap if some force pushes the system up beyond the point of unstable equilibrium. (See R. R. Nelson, loc. cit.) Since the empirical evidence indicates that the low-level equilibrium was not escaped in either of these ways, we are interested here only in area in the vicinity of the low-level equilibrium; hence the precise shape of the curve is not important.

The v curve has fairly complicated determinants. For consideration of the two factor case, substitution of a \dot{K}/K curve ($\dot{K}/K = sY/K$, where s = the ratio of saving to income) permits a more elegant discussion, but use of this curve becomes unmanageable when land is introduced into the argument.

It should be noted that each v curve is a long-run curve; i.e., each assumes the prevalence throughout all income levels of the S/Y rate and the level of techniques associated with that curve. Movement from one curve to a higher one because of an increase in the S/Y rate will initially overshoot the higher curve and then asymptotically drop down to it. The initial path of movement following such a shift may be concave upward over an interval during which the v curve itself is concave downward. While the shape of the time path, resulting from the timing of the upward shift, will affect the path of movement of the system over time, and therefore the level of aggregate income and population at any given moment in time, it will not materially affect the argument.

above, as at y_1 , at any point to the left of the intersection $v > r$, thus raising y , while at any point to the right $v < r$, thus lowering y . I.e., at y_1 there is a stable equilibrium in y . If by a fortunate accident, or a lump contribution of capital from outside the system, y were raised above y_1 , increase in population at a higher rate than in aggregate income would force it down again. This is the "Malthusian income trap."²²

It is assumed that zero saving and zero population growth occur at the same value of y . This assumption, which is not in the least necessary, satisfies the simplest form of the Malthusian notion of a subsistence level of income. In Figure 1, let this point be y_1 .

Suppose now that through some exogenous force the v function shifts upward. In this two-factor model, v and r will reach a new stable equilibrium, as at y_2 . Population, capital, and aggregate income will increase indefinitely at a constant proportional rate, while y remains constant at an increased level. If the intersection is in the horizontal section of the v curve, as at y_3 , then capital, population and aggregate income race upward at equal rates, and one equal also to the biological maximum possible rate of population increase. The rapid increase in population (labor inputs) causes no tendency for y to decline, since labor force increase runs into no

22. The phrase "Malthusian trap" is Nelson's loc. cit.

scarce cooperant factor.

Suppose, however, that we assume the existence of a third factor, land, which is augmentable only at increasing cost per unit (or, if you choose, is available in absolutely limited supply). Then the value of v at any given level of y will depend not only on the level of techniques and the rate of saving, but also on the quantity of capital and labor. As C and P increase, the productivity at the margin of increments of capital and labor (for convenience think of a combined unit of capital and labor) will diminish after a point, and after a further point v will fall. This fall in v without change in the ratio of C to P constitutes a downward shift in the v function.²³ This downward shift, inevitable in the absence of a renewed force tending to push the function upward, will continue until y has returned to the subsistence level.

Above some level of y , there may be a "standard-of-living" effect on birth rates. In Figure 1, let y_{SL} be this point. Then if the v curve shifts upward to the position v^0 , intersecting the r curve to the right of y_{SL} , as at y_4 , the effect of experiencing this level of living will be to shift the r curve downward to the position r^0 , and continued capital formation even without technical advance will cause y to rise to y_5 . However, y will thereafter decline, if the limitation

23. And is to be contrasted with movement along the curve because of change in the C/P ratio.

on land supply continues to exert its influence, since that limitation will press the v curve steadily downward and thus move y steadily to the left.

I have referred to the decline in birth rates as due to a "standard-of-living" effect. However, I use this term in a broad sense. It should not be assumed that the direct operating force is necessarily the increase in per capita income. The rise in per capita income is accompanied by a shift in the occupational composition of the labor force, urbanization, and a decline in death rates. Somewhere within this complex is the force that produces the "standard-of-living" effect; what component of the complex directly exercises the influence on birth rates need not be examined at this point.

Historically, in no case as per capita income rose did the rate of population growth reach (or approach) the practical biological maximum, as the model requires, and in no case has per capita income turned downward secularly. We are looking for a mechanism that will explain these two phenomena. One is found in the assumption of continuing technological progress, combined with certain plausible assumptions about the operation of the model.

Note first that any single improvement in technology shifts the v curve upward, for it increases the output of a combination of capital and labor inputs in the production of some product, and thereby increases both the increment of aggregate output each time that

product (or an adaptation of it involving in some degree the same method) is produced, and the likelihood that that product will be chosen for production (its unit cost being reduced). Since this is the effect of a single improvement in technology, continuing technological progress tends to push the v function continually upward.

But, as sketched above, at any level of income above subsistence diminishing returns to capital and labor with respect to land exerts downward pressure on the v function. This downward pressure counters in some degree the tendency to continual rise of the function. Further, this downward pressure increases over time, since capital and labor increase in quantity over time. (The higher the level of the v function, the more rapidly the downward pressure increases, since C and L are increasing more rapidly.) Continuing technological progress will therefore push the v function upward for a time, but eventually (with any given pace of technological progress) the rise will gradually be halted and then gradually reversed, thus also gradually checking and then reversing a rise in y . For a time, the position of the v curve will be virtually constant.

The simple assumption of land augmentability only at increasing cost is not realistic. The model is more relevant to reality if instead it is assumed that technological progress increases the quantity of land, making the upward or downward drift of the v function a matter of the specific parameters employed. However, it may be well

to carry through the analysis on the assumption of land augmentable only at increasing cost, since this is Malthus' assumption.

Let us now make the further assumption that a "standard-of-living effect" occurs at any level of income above the subsistence level, if income is sustained above subsistence for a minimum period (say the period from early infancy to parenthood). There is no reason in logic to assume any specific floor of per capita income, below which the standard-of-living effect does not occur. It follows that technological progress at any rate whatever will cause a standard-of-living

effect, unless land stringency is so great and technological progress so slight that the system rises from and then returns to the subsistence level of y within a few years. With a faster rate of technological progress, holding the v function above subsistence for a sufficient time, there will follow a decline of death and birth rates until both reach minima, after which a rise in per capita income may continue.

The process is illustrated in Figure 2. Let us assume for

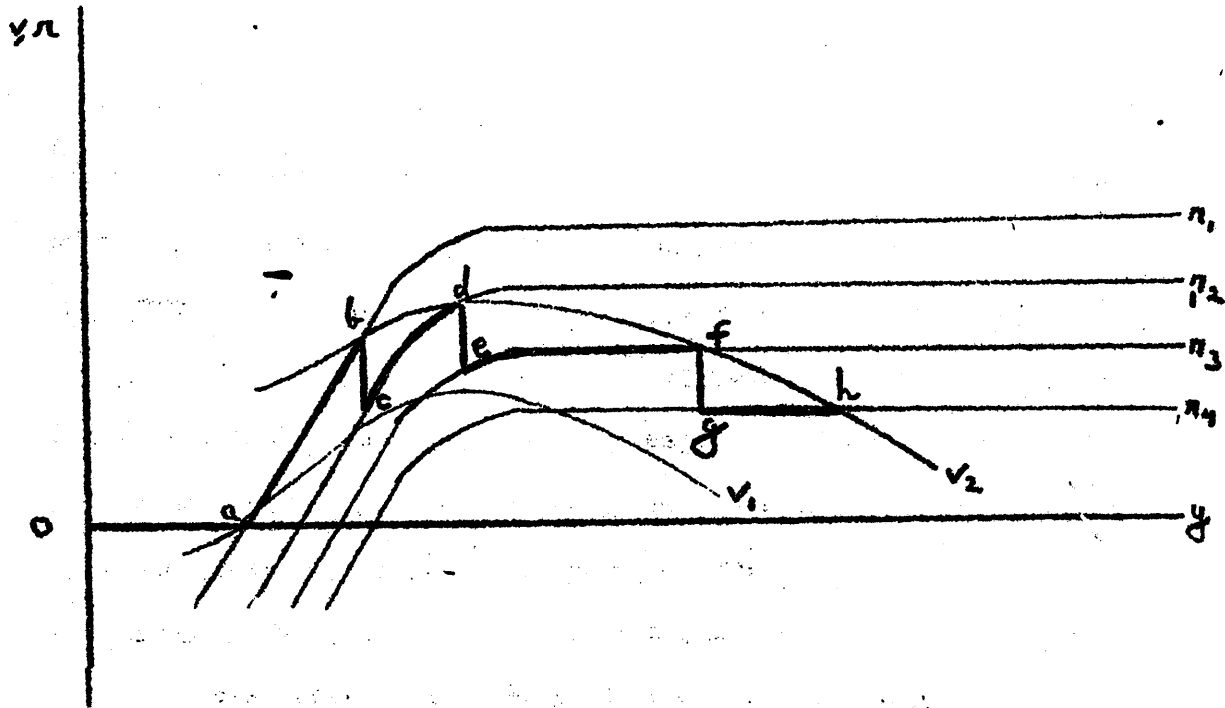


Figure 2: The Standard-of-Living Effect at a Low-Income Level

graphical simplicity that the v function rises to its position 2 and

hovers at that level. The upward shift causes a rise in y and r along the r_1 function to its intersection b with the v function. The rise in r was of course via a fall in death rates. But at the higher level of y , after a lag birth rates will fall (the standard-of-living effect). The resulting fall in the rate of population increase constitutes a fall in the r function, as to position r_2 . r falls from b to c . Since r is now less than v , y and r again rise, this time along the r_2 curve to its intersection d with the v_2 curve. A further standard-of-living effect occurs, and the process is repeated, r moving from d to e to f to g to h .²⁴ Here the process stops, if we assume that in position h of the r function death rates and birth rates are at their minima, and that at their minima r is zero or positive. The determinants of a death rate minimum--primarily the state of medical and health practices, in peaceful times--need no discussion. The determinants of a birth rate minimum are less clear. They are discussed shortly. Before death and birth rates reached their minima, the system passed through a period of considerable population growth, but the characteristics of the model guaranteed that as aggregate output rose population growth would not rise as fast, i.e., that per capita income would rise cumulatively.

Before the system reaches point h , technological progress may have

24. While Figure 2 portrays the process as a "ratchet" effect, the downward shift of the r function and the rightward shift of the values may be expected to be continuous.

created new land (new minerals, cheaper ways of extracting them from low grade deposits, plastics, new energy sources), thus pushing all or part of the v function upward; or may have created new substitutes for labor (labor-saving inventions), thus flattening out the concavity downward of the function (raising the right-hand portion of the curve), and pushing the intersection h to the right. For one or both reasons, the point h may recede rightward, and rise in per capita income may continue. This has happened to date in the technologically progressive countries of the world, and the two tendencies show no evidence of coming to an end or even slowing down.

I suggest that this model, not a Malthusian one, is the appropriate model for interpreting the population experience of the world during its technological progress to date. To make the model of more general application, i.e. applicable where there is no technological progress, we must incorporate in it the effects of exogenous declines in death rates. The incorporation is mechanically simple, but to understand its significance, as well as to delineate clearly the nature of the minimum position of the r function, in Figure 2, it turns out to be necessary to examine carefully the nature of the forces that cause declines in birth rates.

It would seem at first glance that exogenous declines in death rates in peasant societies may be shown in Figure 1 by a vertical rise of the r curve for some distance from the point y_1 , then a turn

or gradual change of direction to the northeast and continuance to its maximum level. Movement up the vertical segment represents population growth due to exogenous reduction in the death rate, and movement along the rightward sloping segment of the curve represents further decline induced by rise in per capita income and not possible without it.

However, this representation is not quite correct. For the introduction of improved medical and health measures reduces the subsistence level of living. It is now possible to subsist, i.e. it is possible for the population to just reproduce itself, at a lower level of per capita income. Graphically, in Figure 1 the rate of population growth rises vertically above the point y_1 , and at the same time the r curve, retaining its former shape,²⁵ slides to the left so that the new rate of population growth remains on the curve. There is a new subsistence level of income somewhere to the left of y_1 .

What happens thereafter depends in part on the precise nature of the determinants of birth rates. No rise in per capita income has occurred in the society, except in the limited sense indicated in footnote 3. If decline in birth rates results solely from a rise in

25. Of course the slope of the sloping segment may change. With medical improvements of the sort introduced into low-income societies in recent years, the horizontal segment of the curve will also shift upward, because of a changed age distribution and because of better health during child-bearing years, unless the new causes of death mentioned in the text appear in time to prevent the shift.

levels of living (a standard-of-living effect in a narrow sense), then it will not occur unless simultaneously with or soon after the fall in death rates, by coincidence there appears technological progress at a rate sufficient that aggregate income increases at a rate faster than population, i.e., sufficient to raise the v function far enough so that its intersection with the r function in its new position is at a point to the right of y_1 ²⁶. In many peasant societies which have recently experienced exogenous declines in death rates, the rate of increase in aggregate income required would be more than three percent per year. In the absence of such a rate, which seems only a remote possibility in the near future in some of those countries, the intersection of the v and r curves will be to the left of y_1 , and per capita income will fall progressively until death rates have fallen sufficiently, even in the presence of improved public health and medical measures, to restore equilibrium. Starvation and diseases associated with malnutrition will replace malaria, venereal disease, etc., as major causes of death. Social revolution may occur first. It will not directly affect the birth rate. Of course voluntary control of birth rates may also occur first.

If the causal force in the decline of birth rates is industrialization and urbanization, much the same grim prospect exists. For

26. It is possible to assume that the rise in the rate of population growth induces an equal or greater rise in v . The assumption however seems unrealistic and uninteresting.

while flight to the cities is occurring, this is not urbanization in the conventional sense, and probably will not have a sufficient effect on the birth rate average for the population as a whole to remedy the situation sketched here. If, however, another alternative assumption concerning the causal factors is correct, the prospect is somewhat different. Let me make another set of two assumptions, fully consistent with the historical facts.

1. Assume that the level of birth rates is determined by that of death rates. Birth rates are so adjusted to death rates that by intention, at least two children of the typical family grow up to parenthood. More precisely, since in view of the uncertainties of human life to rear precisely two children to parenthood is to cut the probabilities too fine, by intention somewhat more than two are raised to parenthood. Where death rates are at a level that birth rates cannot exceed, this intention is of course frustrated. But where conditions of sustenance permit, the basic long-run rate of population growth is a fairly low positive rate. In equilibrium it does not tend to rise above that. ("Fairly low" may be taken to refer to a rate varying among different societies between say .5% and 1.3% per year.)²⁷

27. For consistency with the findings of modern social science, we must assume that this minimum rate is culturally, not biogenically, determined. Ireland and China may perhaps be taken respectively as extreme cases of low and high tendency to population increase.

This assumption provides a plausible explanation of the apparent²⁸ tendency of birth rates not to fall until death rates are below them by at least the indicated differential.

2. This birth rate and size of family calculus is, however, not primarily conscious and rational,²⁹ but rather is primarily imbedded in unconscious motives³⁰ relating to sex and family inculcated in children during their earliest years,³¹ and reinforced--or altered, with resulting inner conflict--during adolescence. They relate to the number of births, the death rate being a given fact of the environment. Since these sex and progeny mores are transmitted unconsciously by parents (and others), they may change very slowly, and the birth rate may decline only with a lag of one or several generations after the death rate declines.

If this is a correct description of the determinants of birth rates, the so-called standard-of-living effect is not a direct function

28. Available information is not sufficiently accurate for complete certainty.

29. Though, of course, it is rationalized.

30. I use the word "motive" here in its technical psychological sense, as equivalent to the other technical terms "need," "motivation," or (as used by some psychologists) "drive." It does not refer to a conscious purpose.

31. Perhaps during the "genital" period of the ages three to six years, when the relationship that Freud termed the "family romance" appears. Concerning this period, see e.g. O. S. English and G. H. J. Pearson, Emotional Problems of Living (New York, 1945). The speculation that this period may be important in the determination of family size is purely my own.

of income level, but a result of the decline in death rates, which makes a reduced birth rate adequate for perpetuation of the family.

We can if we wish tentatively specify some aspects of the shape of the fraction determining the lag. It may vary inversely with the speed and conspicuousness of the fall in death rates, and it may have a minimum length equal to the period from age three to parenthood.

This set of assumptions is consistent with the historical evidence. Unfortunately, however, that evidence provides such meager clues that various other assumptions are also consistent with it. While the set stated above seems to me the most plausible among them, this judgment is not subject to objective verification.

If this set of hypotheses about the determinants of population increase is correct, there is somewhat greater hope for avoiding population catastrophe in the technologically static societies that have recently reduced their death rates sharply. Even so, if the minimum lag between fall in death rates and that in birth rates is a generation or more, the prospect for a number of countries is unpleasant.³²

32. Before the "vital revolution" associated with the Industrial Revolution occurred in Western Europe, birth rates there were around 35 per thousand, or almost ten per thousand below present birth rates in present peasant societies. Some observers see in this fact a cultural (or, conceivably, biogenic) difference that bodes ill for the present peasant societies. The higher birth rates of present peasant societies result in a higher rate of population increase for any given level of death rates. This alone is extremely important. It is also possible that the higher birth rates may be associated with a greater

Through economic growth China is apparently escaping this threat. If **RAPID** economic growth is not achieved in India, a future population explosion may be very serious. The other countries involved are small.

The model presented here may or may not be applicable to the very long run. A word about the very long run is in order. Even at a rate of growth of one percent per year, the world's population would double in 70 years, quadruple in 140, reach a mass equal to that of the earth in a few thousand years, and so on. But this fact does not seem to me the cause for alarm that it appears to some observers. In the intervening period, technology may have developed so that subsistence and energy are obtained from the entire known universe, or several such universes, and only one man in a thousand may be living on the earth. Indeed, present trends suggest, if not specifically this, at least that there is no reason to place any given limit on the creation of new resources by technology. On the other hand, population functions may be radically different from those now operating. Hence it seems reasonable to be more concerned with any of a dozen other world problems than with that of prospective "standing room only."

resistance of birth rates to following death rates downward. On the other hand, it is possible that birth rates in Europe during the Middle Ages, for which we have no data, were also above forty; and that the halting successive technological improvements of the Middle Ages had reduced death rates for a sufficient time to cause a fall in birth rates to about 35, long before the continuing technological improvement of the Industrial Revolution initiated further decline. If so, there is no reason to assume any fundamental difference in behavior between present peasant societies and Western Europe, though of course variation among individual societies is to be expected.

IV. POPULATION GROWTH IN THE WEST SINCE WORLD WAR II

In presenting the model, it remains to consider whether the rise in birth rates in Western Europe and the United States after World War II is consistent with it. Early in the postwar period, birth rates in most Western European countries and in the United States rose to a level not only above those of the depressed 1930's but also well above those of the 1920's, which had been regarded as the basic rates of "mature" societies. The phenomenon has now continued so long, and family sizes have so clearly increased, that at least part of the development must be regarded as reflecting some secular change.³³

A possible explanation is to assume that among the satisfactions to which an increase in income from one generation to the next will be devoted is that of having a larger number of progeny. A rise in income will therefore tend to cause a rise in the population growth rate above the basic long-run level via a declining death rate, if the death rate is in fact declining, and via a rise in the birth rate if the death rate is stationary and the margin between the two provides only the basic rate of growth. The effect is a function of the change

33. Crude birth rates sagged slightly during the period 1950-1955 throughout Western Europe, but since this statistical phenomenon would result merely from the increase in the proportion of children in the population, it is not certain that age-specific birth rates have fallen at all. These are not yet available for recent years. In England, Finland, the Netherlands, and Sweden, a decline too great to be accounted for in this way had occurred by 1954.

in income, not the level of income. The population growth rate tends to fall back to the basic level if the rise in income comes to an end, even though the higher level of income persists. Assumption of a lag of a generation at the turnaround in birth rates would explain the continuing downward trend of birth rates after death rates in the early decades of the twentieth century, so that both were at minima during the 1920's even though incomes were rising.

This explanation is rather forced. It assumes a purely rational calculation, in addition to the rationalized version of unconscious motives assumed above. The two assumptions may be psychologically contradictory. It may be that the recent rise in birth rates results instead from a more immediate connection between creative energy and sexual activity, and that the sources--whatever they may be--of the creative energy which has lifted output rapidly after World War II are also the sources of the current desire among young parents for larger families. So far as our uncertain historical knowledge indicates, this latter hypothesis is consistent with the behavior of population during early periods of industrialization. On the other hand, it can be fitted to the facts of the 1920's only with some difficulty.

One may therefore have to resort to saying simply that the rise in birth rates after World War II constitutes a shift in the population function, resulting perhaps from the successive stresses of depression, war, and postwar tensions. Whatever the true reason for the post-

World-War-II rise in the birth rate may be, any very penetrating explanation of it will undoubtedly have to wait until the theory of personality formation has advanced beyond its present state. But none of the hypotheses that suggest themselves now are inconsistent with those presented above relating to other aspects of population growth.

A model embodying the assumptions presented in this section, including the first alternative in paragraph 4, is suggested in a mathematical appendix.

V. THE MALTHUSIAN MODEL

The reader, if he has a Malthusian model in mind, will have observed that the model presented here differs from it in various particulars. This is obvious even though Malthus' presentation in successive issues of the Essay and in the Supplement to the Fifth Edition of the Encyclopedia Britannica varies sufficiently in specifics and is sufficiently lacking in rigor so that it is difficult to reach an agreed-on simple statement of the model. But perhaps the following five points, either because of explicit statement by Malthus or by the requirements of the model, may be regarded as essential points.

1. The birth rate is not influenced by the level of income, and implicitly not by death rates. As a result, a decline in the death

rate simply increases the rate of population increase. (Malthus does not make clear the role of birth and death rates respectively in population increase. The first sentence in this paragraph is an extension of his position rather than a simple statement of it. He asserts simply that people tend to have as large families as they can provide subsistence for.)

2. Land is augmentable only at increasing cost.

3. A law of variable proportions operates.

4. Some sort of restriction on capital accumulation operates, so that capital accumulation cannot offset the limitation on quantity of land sufficiently to prevent per capita income from falling as population rises.

5. Technology is constant--or, technological progress is not related in any causal way to population growth, but if it occurs is only a coincidental development that may for a time stave off the results of diminishing returns.

The initial statement of a model associated with Figure 1 incorporates these assumptions, with the exception that a neo-Malthusian standard-of-living effect at a fairly high level of income is posited. It follows, as it does from any rigorous formulation of a Malthusian model, that if some force (not explained by the model) causes growth in aggregate income, it can (in the absence of moral self-restraint concerning procreation) increase per capita income much above subsistence only if the rate of growth in aggregate income exceeds the maximum possible rate of population growth. The unrealistic assumptions would

not be objectionable if they resulted in an analysis that satisfactorily explained reality. But the conclusion just stated contradicts the central facts of population history.

Important Malthusian strains have persisted in our thinking and in university teaching. I suspect that they have persisted largely because the model predicts population growth, population growth has occurred, and we have not had a satisfactory alternative explanation. It is of course important to retain the simple notion that rise of income above subsistence tends to result in population growth. But we need to analyze that growth by tools more relevant than the Malthusian ones. Even if the model presented here should prove unsatisfactory, the contradiction between Malthusian analysis and the facts of population history suggests that the Malthusian model is an impediment, not an aid, to our thinking about population.

Algebraic Appendix

The model which has been outlined in Sections III and IV may be described algebraically as follows:

$$D_t = D(y_{t-n}, M) \quad (1)$$

$$n > 1$$

where D = the ratio of deaths per year to total population

y = per capita income

t = the time period, measured in units of generations,

n = a time interval measured in the same units, and

M = the state of medical practice in the country, e.g. as evaluated on an index by a world board of medical examiners.

$$B_t = B_t^0 + B_t^* \quad (2)$$

$$B_t^0 = B^0(D_t, D_{t-1}, \dots, D_{t-n}) \quad (3)$$

$$B_t^* = \max_{B^*} \left[(B_{t-1} - D_{t-1}), \frac{y_t}{y_{t-1}} \right] \quad (4)$$

where B_t = the ratio of births per year to total population during the generation t .

B_t^0 depends on the death rate in the previous generation and on the rate of change in the death rate during the previous n generations; and

B_t^* , the component which is related to increase in income, depends on

the rate of population growth not so related in the previous generation, and on the rate of increase in per capita income between the previous generation and the present one. The max notation indicates that there is a maximum to the increase-in-income effect.

$$P_t = B_t - D_t \quad (5)$$

where P_t = the ratio of increase in population per year to total population.

The shape of the several functions may be indicated more specifically as follows:

$$D_t = D(y_{t-1}, M) \quad (1a)$$

$$B_t^0 = k + D_{t-3} - \lambda(D_{t-3} - D_{t-2}) - \lambda'(D_{t-3} - D_{t-1}) - \lambda''(D_{t-3} - D_t) \quad (3a)$$

where $k = \bar{K}$, a positive constant, if $y_t \geq y_s + E$

$$k = fy_t, \text{ if } y_t < y_s + E$$

$$\lambda < \lambda' < \lambda'', \text{ and } \lambda + \lambda' + \lambda'' = (\text{approx.}) 1.$$

$$B_t^* = \left[q - (B_{t-1}^0 - D_{t-1}) \right] \cdot \left[r \left(\frac{y_t - y_{t-1}}{y_{t-1}} \right) \right] \quad (4a)$$

where $B_t^0 + B_t^* \geq q$ or B_t^0 , whichever is the greater, and where the term $(B_{t-1}^0 - D_{t-1})$ is limited to the domain between zero and q inclusive, and the term in the second set of brackets to a domain having a maximum value of unity. In equations (3a) and (4a), λ , λ' , λ'' , q , and r are positive constants, and y_s = the subsistence level of per capita income.

\bar{k} is the "basic" rate of population increase. In equilibrium, the birth rate will in general exceed the death rate by this amount. However, if y is at the subsistence level, k becomes zero, and below the subsistence level, becomes negative. If the death rate declined during generation $t-1$ or $t-2$, the excess of the birth rate over the death rate will be greater than \bar{k} . However, the effect of a death rate decline in generation $t-3$ is virtually fully reflected in the birth rate by generation t . If there has been no subsequent fall in the death rate, $D_{t-2} = D_{t-1} = D_t$, and, since $q + q' + q'' = (\text{approx.}) 1$, equation (3a) becomes: $B_t^0 = k + D_t$.

In equation (4a), since B_t^* is a product of the two terms in brackets, it is zero if either is zero. The term in the first set of brackets indicates that the change-in-income effect on P does not add to other factors to cause population increase above a maximum q . The term in the second set of brackets indicates that if per capita income is identical with that of the previous generation, there is zero effect. If $y_t > y_{t-1}$, the change-in-income effect is of course negative. To assume that r remains constant if y declines is of course a heroic simplification.

All of the parameters, being culturally determined, vary among societies.