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IS GROWTH OBSOLETE?

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A long decade ago economic growth was the reigning fashion of
political economy. It was simultaneously the hottest subject of
economic theory and research, a slogan eagerly claimed by politi-
cians of all stripes, and a serious objective of the policies of
governments. The climate of opinion has changed dramatically.
Disillusioned critics indict both economic science and economic policy
for blind obeisance to aggregate material "progress," and for neglect
of its costly side effects. Growth, it is charged, distorts national
priorities, worsens the distribution of income, and irreparably
damages the environment. Paul Erlich speaks for a multitude when
he says, "We must acquire a life style which has as its goal maximum
freedom and happiness for the individual, not a maximum Gross
National Product."

Growth was in an important sense a discovery of economics after
the second world war. Of course economic development has always
been the grand theme of historically minded scholars of large mind
and bold concept, notably Marx, Schumpeter, Kuznets. But the main-
stream of economic analysis was not comfortable with phenomena of
change and progress. The stationary state was the long-run equilibrium

of classical and neoclassical theory, and comparison of alternative static equilibria was the most powerful theoretical tool. Technological change and population increase were most readily accommodated as one-time exogenous shocks; comparative static analysis could tell how they altered the equilibrium of the system. The obvious fact that these "shocks" were occurring continuously, never allowing the system to reach its equilibrium, was a considerable embarrassment. Keynesian theory fell in the same tradition, attempting rather awkwardly, though nonetheless fruitfully, to apply static equilibrium theory to the essentially dynamic problem of saving and capital accumulation.

Sir Roy Harrod in 1940 began the process, brought to fruition by many theorists in the 1950s, of putting the stationary state into motion. The long-run equilibrium of the system became a path of steady growth, and the tools of comparative statics could then be applied to alternative growth paths rather than to alternative stationary states. Neo-Keynesian macro-economics began to fall into place as a description of departures from equilibrium growth, although this task of re-interpretation and integration is still far from satisfactory completion.

By now modern neoclassical growth theory is well enough formulated to make its way into textbooks. It is a theory of the growth of potential output, or output at a uniform standard rate of utilization of capacity. The theory relates potential output to three determinants: the labor force, the state of technology, and the stock of human and tangible capital. The first two are usually assumed to grow

smoothly at rates determined exogenously by non-economic factors.
The accumulation of capital is governed by the thrift of the population, and in equilibrium the growth of the capital stock matches
the growth of labor-cum-technology and the growth of output. Simple
as it is, the model fits the observed trends of economic growth
reasonably well.

The steady equilibrium growth of modern neoclassical theory is,
it must be acknowledged, a routine process of replication. It is a
dull story compared to the convulsive structural, technological, and
social changes described by the historically oriented scholars of development mentioned above. The theory conceals, either in aggregation
or in the abstract generality of multi-sector models, all the drama --
the rise and fall of products, technologies, and industries, and the
accompanying transformations of the spatial and occupational distributions of the population. Many economists agree with the broad outlines of Schumpeter's vision of capitalist development, which is a far
cry from growth models made nowadays in either Cambridge, Massachusetts
or Cambridge, England. But visions of that kind have yet to be transformed into a theory that can be applied in every-day analytic and empirical work.

In any case, growth of some kind is now the recognized economic
norm. A symptom of the change in outlook can be found in business
cycle semantics. A National Bureau recession was essentially a period
in which aggregate productive activity was declining. Since 1960 it has

become increasingly customary to describe the state of the economy
by the gap between its actual output and its growing potential.
Although the word recession is still a source of confusion and con-
troversy, almost everyone recognizes that the economy is losing
ground -- which will have to be recaptured eventually -- whenever
its actual rate of expansion is below the rate of growth of poten-
tial output.

In the early 1960s growth became a proclaimed objective of gov-
ernment policy, in this country as elsewhere. Who could be against
it? But like most value-laden words, growth has meant different
things to different people and at different times. Often growth policy
was simply identified with measures to expand aggregate demand in or-
der to bring or keep actual output in line with potential output. In
this sense it is simply stabilization policy, only more gap-conscious
and growth-conscious than the cycle-smoothing policies of the past.

To economists schooled in postwar neoclassical growth theory,
growth policy proper meant something more than this, and more debatable.
It meant deliberate effort to speed up the growth of potential output
itself, specifically to accelerate the productivity of labor. Growth
policy in this meaning was not widely understood or accepted. The neo-
classical model outlined above suggested two kinds of policies to
foster growth, possibly interrelated: measures that advance technological
knowledge and measures that increase the share of potential output devoted

to accumulation of physical or human capital. [1] The standard model also suggested that, unless someone could find a way to accelerate technological progress permanently, policy could not raise the rate of growth permanently. One-shot measures will speed up growth temporarily, for years or decades. But once the economy has absorbed these measures, its future growth rate will be limited once again by constraints of labor and technology. The level of its path, however, will be permanently higher than if the policies had not been undertaken.

Growth measures nearly always involve diversions of current resources from other uses, sacrifices of current consumption for succeeding generations of consumers. Enthusiasts for faster growth are advocates of the future against the present. Their case rests on the view that the market economy, left to itself, will short-change the future by saving too small a fraction of current output. We mention this point now because we shall return later to the ironical fact that the anti-growth men of the 1970s believe that it is they who represent the claims of a fragile future against a voracious present

Like the enthusiasts to whom they are a reaction, current critic of growth are disenchanted with both theory and policy, with both the descriptive and the normative implications of the doctrines of the pre

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1/. The variety of possible measures, and the difficulty of raising the growth rate by more than one or two percentage points, have been explored by Edward Denison in his influential study, The Sources of Economic Growth in the United States and the Alternatives Before Us, A Supplementary Paper of the Committee for Economic Development, 1962.

vious decade. The sources of disenchantment are worth considering today, because they indicate agenda for future theoretical and empirical research.

We have chosen to direct our attention to three important problems raised by those who question the desirability and possibility of future growth: (1) How good are measures of output currently used for evaluating the growth of economic welfare? (2) Does the growth process inevitably waste our natural resources? (3) How does the rate of population growth affect economic welfare? In particular, what would be the effect of zero population growth?

Measures of Economic Welfare

A major question raised by critics of economic growth is whether we have been growing at all in any meaningful sense. Gross National Product statistics cannot give the answers, for GNP is not a measure of economic welfare. Erlich is right that maximization of GNP is not a proper objective of policy. Economists all know that, and yet common use of GNP as the standard measure of economic performance apparently conveys the impression that they are evangelistic worshipers of GNP.

An obvious shortcoming of GNP is that it is an index of production, not consumption. The goal of economic activity, after all, is consumption. Although this is the central premise of economics, the profession has been slow to develop, either conceptually or statistically, a measure of economic performance oriented to consumption, broadly defined and carefully calculated. We have constructed a primitive and experimental Measure of Economic Welfare (MEW), in which we attempt to allow for the more obvious discrepancies between GNP and economic welfare. A complete account is given in Appendix A. The main results will be discussed here and summarized in Tables 1 and 2.

In proposing a welfare measure, we in no way deny the importance of the conventional national income accounts or of the output measures based upon them. Our MEW is largely a rearrangement of items of the national accounts. Gross and Net National Product statistics are the

economists' chief tools for short-run analysis, forecasting, and policy and are also indispensable for many other purposes.

Our adjustments to GNP fall into three general categories: reclassification of GNP expenditures as consumption, investment, and intermediate; imputation for the services of consumer capital, for leisure, and for the product of household work; correction for some of the disamenities of urbanization.

1. Reclassification of GNP final expenditures. Our purposes are first, to subtract some items that are better regarded as instrumental and intermediate than as final output, and second, to allocate all remaining items between consumption and net investment. Since the national accounts do not differentiate government purchases of goods and services, one of our major tasks is to split them among the three categories: intermediate, consumption, net investment. We have also reclassified some private expenditures.

Intermediate products are goods and services whose contributions to present or future consumer welfare are completely counted in the values of other goods and services. To avoid double counting they should not be included in reckoning the net yield of economic activity. Thus all national income accounts reckon as final consumption the bread but not the flour and as capital formation the finished house but not the lumber. The more difficult and controversial issues in assigning items to intermediate or final categories are the following:

Capital consumption. The depreciation of capital stocks is a cost of production, and output required to offset the depreciation is intermediate as surely as materials consumed in the productive process. For most purposes, including welfare indexes, NNP is preferable to GNP. Only the difficulties and lags in estimating capital consumption have made GNP the popular statistic.

However, NNP itself fails to treat many durable goods as capital, and counts as final their entire output whether for replacement or accumulation. These elementary points are worth repeating because some of our colleagues are telling the public that economists glorify wasteful "through-put" for its own sake. Focus on NNP, and accounting for all durables as capital goods, would avoid such foolish paradoxes as the implication that deliberate efforts to make goods more perishable raise national output. We estimate, however, that proper treatment of consumer durables has little quantitative effect: see Table 1, lines 3 and 5.

The other capital consumption adjustments we have made arise from allowing for government capital and for the educational and medical capital embodied in human beings. In effect, we have reclassified education and health expenditures, both public and private, as capital investments.

Growth requirements. In principle Net National Product tells how much consumption the economy could indefinitely sustain. GNP does not tell that; consuming the whole GNP in any year would impair future

consumption prospects. But per capita rather than aggregate consumption is the welfare objective; neither economists nor other observers would as a rule regard sheer increase in the numbers of people enjoying the same average standard of living as a gain in welfare. Even NNP exaggerates sustainable per capita consumption, except in a society with stationary population -- another example of the pervasiveness of the stationarity assumption in the past. Per capita consumption cannot be sustained with zero net investment; the capital stock must be growing at the same rate as population and labor force. This capital-widening requirement is as truly a cost of staying in the same position as outright capital consumption.[1]

This principle is clear enough when growth is simply increase in population and labor force. Its application to an economy with technological progress is by no means clear. Indeed, the very concept of national income becomes fuzzy. Should the capital-widening requirement then be interpreted to mean that capital should keep pace with output and technology, not just with the labor force? If so, the implied

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[1]. Consider the neo-classical model without technological change. When labor force is growing at rate g , the capital-labor ratio is k , gross product per worker is $f(k)$, net product per worker is $f(k) - \delta k$, then the net investment requirement is gk , and sustainable consumption per worker is $f(k) - \delta k - gk$.

Denoting the capital-output ratio as $\mu = \dfrac{k}{f(k)}$, sustainable consumption per worker can also be written as $f(k)(1-\mu(\delta+g))$. Although NNP embodies in principle the depreciation deduction δk , it does not take account of the capital-widening requirement gk .

sustainable consumption per capita grows with the rate of tech-
nological progress. This is the point of view which we have taken
in what follows. On the other hand, a given level of consumption
per capita could be sustained with a steady decline in the capital/
output ratio, thanks to technological progress. [1]

The growth requirement is shown as line 7 of Table 2 . This
is clearly a significant correction, measuring about 16 percent of
GNP in 1965.

Our calculations distinguish between actual and sustainable per
capita consumption. Actual MEW may exceed or fall short of sustainable
MEW, the amount that could be consumed while meeting both capital con-
sumption and growth requirements. If these requirements are met, per
capita consumption can grow at the trend rate of increase in labor
productivity. When actual MEW is less than sustainable MEW, the economy
is making even better provision for future consumers; when actual MEW
exceeds sustainable MEW, current consumption in effect includes some of
the fruits of future progress.

1/. As is well known, the whole concept of equilibrium growth collapses
unless progress is purely labor-augmenting, "Harrod-neutral." In
that case the rate g above is $n+\gamma$, where n is the natural rate
of increase and γ is the rate of technological progress, and "labor
force" means effective or augmented labor force. In equilibrium, out-
put and consumption per natural worker grow at the rate γ , and
"sustainable" consumption per capita means consumption growing steadily
at this rate. Clearly level consumption per capita can be sustained
with smaller net investment than $g_u f(k)$, so that μ and k
steadily decline. See Appendix A, section

Instrumental expenditures. Since GNP and NNP are measures of production rather than of welfare, they count many activities that are evidently not directly sources of utility themselves but are regrettably necessary inputs to activities that may yield utility. Some government "purchases" are of this nature -- for example, police services, sanitation services, road maintenance, national defense. Some expenditures on these items are among the necessary overhead costs of a complex industrial nation-state, although there is plenty of room for disagreement as to the necessary amounts. We are making no judgments on such issues in classifying these outlays as intermediate rather than final uses of resources. Likewise some consumer outlays are only instrumental, for example, the costs of commuting to work.

These judgments are difficult and controversial. The issues are clearly illustrated in the important case of national defense.

There are two reasons why we exclude defense expenditures. First, we see no direct effect of defense expenditures on household economic welfare. No reasonable country (or household) buys "national defense" for its own sake. If there were no war or risk of war, there would be no need for defense expenditures and no one would be the worse without them. Conceptually, then, defense expenditures are gross but not net output.

The second reason is that defense expenditures are input rather than output data. Measurable output is especially elusive in the case of defense. Conceptually, the output of the defense effort is national security. Has the value of the nation's security risen from $0.5 billion to $50 billion over the period 1929 to 1965? Obviously not.

It is patently more reasonable to assume that the rise in expenditure was due to deterioration in international relations and to changes in military technology. The cost of providing a given level of security has risen enormously. If there has been no corresponding gain in security since 1929, the defense cost series is a very misleading indicator of improvements in welfare.

. The economy's ability to meet increased defense costs speaks well for its productive performance. But the diversion of productive capacity to this purpose cannot be regarded simply as a shift of national preferences and product mix. Just as we count technological progress, managerial innovation, and environmental change when they work in our favor (consider new business machines or mineral discoveries) so we must count a deterioration in the environment when it works against us (consider bad weather and war.) From the point of view of economic welfare, an arms control or disarmament agreement which would free resources and raise consumption by ten percent would be just as significant as new industrial processes yielding the same gains.

In classifying defense costs -- or police protection or public health expenditures -- as regrettable and instrumental, we certainly do not deny the possibility that given the unfavorable circumstances that prompt these expenditures consumers will ultimately be better off with them than without them. This may or may not be the case.

The only judgment we make is that these expenditures yield no direct satisfactions. Even if the "regrettable" outlays are rational responses to unfavorable shifts in the environment of economic activity, we believe that a welfare measure, perhaps unlike a production measure, should record such environmental change.

We must admit, however, that the line between final and instrumental outlays is very hard to draw. For example, the philosophical problems raised by the malleability of consumer wants are too deep to be resolved in economic accounting. Consumers are susceptible to influence by the examples and tastes of other consumers and by the sales efforts of producers. Maybe all our wants are just regrettable necessities; maybe productive activity does no better than to satisfy the wants which it generates; maybe our net welfare product is tautologically zero. More seriously, we cannot measure welfare exclusively by the quantitative flows of goods and services. We need other gauges of the health of individuals and societies. These too will be relative to the value systems which determine whether given symptoms indicate health or disease. But the "social indicators" movement of recent years still lacks a coherent, integrative conceptual and statistical framework.

We estimate that overhead and regrettable expenses, so far as we have been able to define and measure them, rose from 8 percent to 16 percent of GNP over the period 1929-1965. See line 4 of Table 2.

2. Imputations for capital services, leisure, and nonmarket work. In the national income accounts, rent is imputed on owner-occupied homes and counted as consumption and income. We must make similar imputations in other cases to which we have applied capital accounting. Like owner-occupied homes, other consumer durables and public investments yield consumption directly, without market transactions. In the case of educational and health capital, we have assumed the yields to be intermediate services rather than direct consumption. That is, we expect to see the fruits of investments in education and health realized in labor productivity and earnings, and we do not count them twice. Our measure understates economic welfare and its growth to the extent that education and medical care are direct rather than indirect sources of consumer satisfaction.

The omission of leisure and of nonmarket productive activity from measures of production conveys the impression that economists are blindly materialistic. Economic theory teaches that welfare could rise, even while NNP falls, as the result of voluntary choices to work for pay fewer hours per week, weeks per year, years per lifetime.

These imputations unfortunately raise serious conceptual questions, discussed at some length in Appendix A, section A.3. Suppose that in calculating aggregate dollar consumption the hours devoted to leisure and nonmarket productive activity are valued at their presumed opportunity cost, the money wage rate. In converting current dollar consumption to constant dollars, what assumption should

be made about the unobservable price indexes for the goods and ser-
vices consumed during those hours? The wage rate? The price index
for marketed consumption goods? In forty years the two diverge sub-
stantially; the choice between them makes a big difference in esti-
mates of the growth of MEW. As explained in Appendix A, the market
consumption "deflator" should be used if technological progress has
augmented nonmarketed uses of time to the same degree as marketed
labor. The wage rate should be the deflator if no such progress has
occurred in the effectiveness of unpaid time.

We provide in Tables 1 and 2 calculations for three conceptual
alternatives. Our own choice is variant B of MEW which deflates the
value of leisure by the wage rate and the value of nonmarket activity
by the consumption deflator.

3. Disamenities of urbanization. The national income accounts
largely ignore the many sources of utility or disutility that are not
associated with market transactions or measured in the market value
of goods and services. If one of my neighbors cultivates a garden of
ever-increasing beauty, and another makes more and more noise, neither
my increasing appreciation of the one nor my growing annoyance with
the other comes to the attention of the Department of Commerce.

Likewise there are some socially productive assets (like the
environment) that do not appear in any balance sheets. Their ser-
vices to producers and consumers are not valued in calculating
national income. By the same token no allowance is made for depletion
of their capacity to yield services in the future.

Many of the negative "externalities" of economic growth are connected with urbanization and congestion. The secular advances recorded in NNP figures has accompanied a vast migration from rural agriculture to urban industry. Without this occupational and residential revolution we could not have enjoyed the fruits of technological progress. But some of the higher earnings of urban residents may simply be compensation for the disamenities of urban life and work. If so we should not count as a gain of welfare the full increments of NNP that result from moving a man from farm or small town to city. The persistent association of higher wages with higher population densities offers one method of estimating the costs of urban life as they are valued by people making residential and occupational decisions.

As explained in Appendix A, section A.4, we have tried to estimate by cross-section regressions the income differentials necessary to hold people in localities with greater population densities. The resulting estimates of the disamenity costs of urbanization are shown as line 8 of Table 1. As can be seen, the estimated disamenity premium is quite substantial, running about 5 percent of GNP. Nevertheless, the urbanization of the population has not been rapid enough so that charging it with this cost significantly reduces the estimated rate of growth of the economy.

The adjustments leading from national accounts "personal consumption" to MEW consumption are shown in Table 1, and the relations of GNP, NNP, and MEW are summarized in Table 2. For reasons previously indicated, we believe that a welfare measure should have the dimension _per capita_. We would stress the per capita MEW figures shown in Tables 1 and 2.

Although the numbers presented here are very tentative, they do suggest the following observations. First, MEW is quite different from conventional output measures. Some consumptions items omitted from GNP are of substantial quantitative importance. Second, our preferred variant of ∧MEW has been growing
per capita
slower than per capita NNP (1.1 percent for MEW as against 1.7 percent for NNP, at annual rates over the period 1929-1965). Yet MEW has been growing. The progress indicated by conventional national accounts is not just a myth that evaporates when a welfare-oriented measure is substituted.

TABLE 1.   Measures of Economic Welfare, Actual and Sustainable

[billions of dollars, 1958 prices]

			1929	1935	1945	1947	1954	1958	1965
1.	Personal Consumption, NIPA *		139.6	125.5	183.0	206.3	255.7	290.1	397.7
2.	Private Instrumental Expenditures		-10.3	-9.2	-9.2	-10.9	-16.4	-19.9	-30.9
3.	Durable Goods Purchases		-16.7	-11.5	-12.3	-26.2	-35.5	-37.9	-60.9
4.	Other Household Investment		-6.5	-6.3	-9.1	-10.4	-15.3	-19.6	-30.1
5.	Services of Consumer Capital Imputation		24.9	17.8	22.1	26.7	37.2	40.8	62.3
6.	Imputation for Leisure	B	339.5	401.3	450.7	466.9	523.2	554.9	626.9
		A	339.5	401.3	450.7	466.9	523.2	554.9	626.9
		C	162.9	231.3	331.8	345.6	477.2	554.9	712.8
7.	Imputation for Nonmarket Activities	B	85.7	109.2	152.4	159.6	211.5	239.7	295.4
		A	178.6	189.5	207.1	215.5	231.9	239.7	259.8
		C	85.7	109.2	152.4	159.6	211.5	239.7	295.4
8.	Disamenity Correction		-12.5	-14.1	-18.1	-19.1	-24.3	-27.6	-34.6
9.	Government Consumption		.3	.3	.4	.5	.5	.8	1.2
10.	Services of Government Capital Imputation		4.8	6.4	8.9	10.0	11.7	14.0	16.6
11.	Total Consumption = Actual MEW	B	543.8	619.4	768.8	803.4	948.3	1035.3	1243.6
		A	641.7	699.7	823.5	859.3	968.7	1035.3	1208.0
		C	372.2	449.4	649.9	682.1	902.3	1035.3	1329.5
12.	MEW Net Investment		-5.3	-46.0	-52.5	55.3	13.0	12.5	-2.5
13.	Sustainable MEW	B	543.5	573.4	716.3	858.7	961.3	1047.8	1241.1
		A	636.4	653.7	771.0	914.6	981.7	1047.8	1205.5
		C	366.9	403.4	597.4	737.4	915.3	1047.8	1327.0

TABLE 1.   (Continued)

[billions of dollars, 1958 prices]

			1929	1935	1945	1947	1954	1958	1965
14.	Population		121.8	127.3	140.5	144.7	163.0	174.9	194.6
15.	Actual NIW per capita (dollars)	B	4506	4866	5472	5552	5818	5919	6391
		A	5268	5496	5861	5938	5943	5919	6208
		C	3056	3530	4626	4714	5536	5919	6832
16.	Per Capita NIW[*], Index 1929 = 100	B	100.0	108.0	121.4	123.2	129.1	131.4	141.8
		A	100.0	104.3	111.3	112.7	112.8	112.4	117.8
		C	100.0	115.5	151.4	154.3	181.2	193.7	223.6
17.	Sustainable NIW per capita (dollars)	B	4462	4504	5098	5934	5898	5991	6378
		A	5225	5135	5488	6321	6023	5991	6195
		C	3012	3169	4252	5096	5615	5991	6819
18.	Per Capita NIW[*], Index 1929 = 100	B	100.0	100.9	114.3	133.0	132.2	134.3	142.9
		A	100.0	98.3	105.0	121.0	115.3	114.7	118.6
		C	100.0	105.2	141.2	169.2	186.4	198.9	226.4
19.	Per capita NNP Dollars		1545	1205	2401	2038	2305	2335	2897
	1929 = 100		100.0	78.0	155.4	131.9	149.2	151.1	187.5

[*] National Income and Product Accounts.

Source: See Appendix Table A-16.

Note: Variants A, B, C in the table correspond to different assumptions about the bearing of technological progress on leisure and nonmarket activities. Variant A assumes that neither has benefited from technological progress at the rate of increase of real wages; variant C assumes that neither has so benefited; variant B assumes that leisure has not been augmented by technological progress but other nonmarket activities have benefited. See Appendix A, section A.3.2 for explanation.

TABLE 2. Gross National Product and MEW

[billions of dollars, 1958 prices]

	1929	1935	1945	1947	1954	1958	1965
1. Gross National Product	203.6	169.5	355.2	309.9	407.0	447.3	617.8
2. Capital Consumption, NIPA*	-20.0	-20.0	-21.9	-18.3	-32.5	-38.9	-54.7
3. Net National Product, NIPA*.	183.6	149.5	333.3	291.6	374.5	408.4	563.1
4. NIPA* Final Output Reclassified as Regrettables & Intermediates							
a) Government	-6.7	-7.4	-146.3	-20.8	-57.8	-56.4	-63.2
b) Private	-10.3	-9.2	-9.2	-10.9	-16.4	-19.9	-30.9
5. Imputations for items not included in NIPA:*							
a) Leisure	339.5	401.3	450.7	466.9	523.2	554.9	626.9
b) Nonmarket Activity	85.7	109.2	152.4	159.6	211.5	239.7	295.4
c) Disamenities	-12.5	-14.1	-18.1	-19.1	-24.3	-27.6	-34.6
d) Services of public & private capital	29.7	24.2	31.0	36.7	48.9	54.8	78.9
6. Additional Capital Consumption	-19.3	-33.4	-11.7	-50.8	-35.2	-27.3	-52.7
7. Growth Requirement	-46.1	-46.7	-65.8	+5.4	-63.1	-73.9	-101.8
8. Sustainable MEW	543.6	573.4	716.3	838.6	951.3	1047.7	1241.1

* National Income and Product Accounts.

Source: See Appendix Table A-17.

Note: Variants A, B, C in the table correspond to different assumptions about the bearing of tech-
nological progress on leisure and nonmarket activities. Variant A assumes that neither has
benefited from technological progress at the rate of increase of real wages; variant C
assumes that neither has so benefited; variant B assumes that leisure has not been augmented
by technological progress but other nonmarket activities have benefited. See Appendix A,
section A.3.2 for explanation.

Growth and Natural Resources

Calculations like the foregoing are unlikely to satisfy critics
who believe that economic growth per se piles up immense social costs
ignored in even the most careful national income calculations. Faced
with the finiteness of our earth and the exponential growth of economy
and population, the environmentalist sees inevitable starvation. The
specter of Malthus is haunting even the affluent society.

There is a familiar ring to these criticisms. Ever since the
Industrial Revolution pessimistic scientists and economists have
warned that natural resources ultimately limit the possibilities of
economic expansion and that society only makes the eventual future
reckoning more painful by ignoring resource limitations now.

In important part, this is a warning about population growth,
which we consider below. Taking population developments as given,
will natural resources become an increasingly severe drag on economic
growth? We have not found evidence to support this fear. Indeed,
the opposite appears to be more likely; growth of output per capita
will accelerate ever so slightly even as stocks of natural resources
decline.

The prevailing standard model of growth assumes that there are
no limits on the feasibility of expanding the supplies of nonhuman
agents of production. It is basically a two-factor model in which
production depends only on labor and reproducible capital. Land and
resources, the third member of the classical triad, has generally
been dropped. The simplifications of theory carry over into empirical

work. The thousands of aggregate production functions estimated by econometricians in the last decade are labor-capital functions. Presumably the tacit justification has been that reproducible capital is a near-perfect substitute for land and other exhaustible resources, at least in the perspective of heroic aggregation customary in macro-economics. If substitution for natural resources is not possible in any given technology, or if a particular resource is exhausted, we tacitly assume that "land-augmenting" innovations will overcome the scarcity.

These optimistic assumptions about technology stand in contrast to the tacit assumption of environmentalists that no substitutes are available for natural resources. Under this condition, it is easily seen that output will indeed stop growing or decline. It thus appears that the substitutability (or technically, the elasticity of substitution) between the neoclassical factors, capital and labor, and natural resources is of crucial importance to future growth. Although this is an area needing further research, we have made two forays to see what the evidence is. Details are given in Appendix B below.

First we ran several simulations of the process of economic growth in order to see which assumptions about substitution and technology fit the "stylized" facts. The important facts are: growing income per capita and growing capital per capita; relatively declining inputs and income shares of natural resources; and a slowly declining capital-output ratio. Among the various forms of production functions

considered, the following assumptions come closest to reproducing these stylized facts: (1) Either the elasticity of substitution between natural resources and other factors is high -- significantly greater than unity -- or resource-augmenting technological change has proceeded faster than overall productivity, (2) the elasticity of substitution between labor and capital is close to unity.

After these simulations were run, it appeared possible to estimate directly the parameters of the preferred form of production function. Econometric estimates confirm proposition (1) and seem to support the alternative of high elasticity of substitution between resources and the neoclassical factors.

Of course it is always possible that the future will be discontinuously different from the past. But if our estimates are accepted, then continuation of substitution during the next fifty years, during which many environmentalists foresee the end to growth, will witness a small increase -- perhaps in the order of 0.1 percent per annum -- in growth of per capita income.

Is our economy, with its mixture of market processes and governmental controls, biased in favor of wasteful and shortsighted exploitation of natural resources? In considering this charge, two archetypical cases must be distinguished, although many actual cases fall between them. First, there are appropriable resources for which buyers pay market values and users market rentals. Second, there are inappropriable resources, "public goods," whose use appears free to individual producers and consumers but is costly in aggregate to society.

If the past is any guide for the future, there seems to be little reason to worry about the exhaustion of resources which the market already treats as economic goods. We have already commented on the irony that both growthmen and anti-growthmen invoke the interests of future generations. The issue between them is not whether and how much provision must be made for future generations, but in what form it should be made. The growthman emphasizes reproducible capital and education. The conservationist emphasizes exhaustible resources -- minerals in the ground, open space, virgin land. The economist's initial presumption is that the market will decide in what forms to transmit wealth, by the requirement that all kinds of wealth bear a comparable rate of return. Now stocks of natural resources -- for example, mineral deposits -- are essentially sterile. Their return to their owners is the increase in their prices, relative to prices of other goods. In a properly functioning market economy, resources will be exploited at such a pace that their rate of relative price appreciation is competitive with rates of return on other kinds of capital. Many conservationists have noted such price appreciation with horror, but if the prices of these resources accurately reflect the scarcities of the future, they must rise in order to prevent too rapid exploitation. Natural resources should grow in relative scarcity -- otherwise they are an inefficient way for society to hold and transmit wealth compared to productive physical and human capital. Price appreciation protects resources from premature exploitation.

How would an excessive rate of exploitation show up? We would see rates of relative price increase above the general real rate of return on wealth. This would indicate that society had in the past used precious resources too profligately, relative to the tastes and technologies later revealed. The scattered evidence we have indicates little excessive price rise. For some resources, indeed, prices seem to have risen more slowly than efficient use would indicate ex post.

If this reasoning is correct, the nightmare of a day of reckoning and economic collapse when, for example, all fossil fuels are forever gone seems to be based on failure to recognize the existing and future possibilities of substitute materials and processes. As the day of reckoning approaches, fuel prices will provide -- as they do not now -- strong incentives for such substitutions, as well as for conserving supplies. On the other hand, the warnings of the conservationists and scientists do underscore the importance of continuous monitoring of the national and world outlook for energy and other resources. Substitutability might disappear. Conceivably both the market and public agencies might be too complacent about the prospects for new and safe substitutes for fossil fuels. The opportunity and need for fruitful collaboration between economists and physical scientists has never been greater.

Possible abuse of public natural resources is much more serious a problem. It is useful to distinguish local and global ecological disturbances. Local disturbances include transient air pollution,

water pollution, noise pollution, visual disamenities. It is certainly true that we have not charged automobile users and electricity consumers for their pollution of the skies, or farmers and housewives for the pollution of lakes by the run-off of fertilizers and detergents. In that degree our national product series have over-estimated the advance of welfare. Our urban disamenity estimates given above indicate an over-estimate of about 5 percent of total consumption at present.

There are other serious consequences of treating as free things which are not really free. This practice gives the wrong signals for the directions of economic growth. The producers of automobiles and of electricity should be given incentives to develop and to utilize "cleaner" technologies. The consumers of automobiles and electricity should pay in higher prices for the pollution they cause, or for the higher costs of low-pollution processes. If recognition of these costs causes consumers to shift their purchases to other goods and services, that is only efficient. At present over-production of these goods is uneconomically subsidized as truly as if the producers received cash subsidies from the Treasury.

The mistake of the anti-growthman is to blame economic growth per se for the misdirection of economic growth. The misdirection is due to a defect of the pricing system -- a serious but by no means irreparable defect and one which would in any case be present in a stationary economy. Pollutants have multiplied much faster than the

population or the economy during the last thirty years. Although
general economic growth has intensified the problem, it seems to
originate in particular technologies. The proper remedy is to
correct the price system/so as to discourage these technologies.
Zero economic growth is a blunt instrument for cleaner air,
prodigiously expensive and probably ineffectual.

As for the danger of global ecological catastrophes, there is
probably very little that economics alone can say. Maybe we are
pouring pollutants into the atmosphere at such a rate that we will
melt the polar icecaps and flood all the world's seaports. Unfor-
tunately, there seems to be great uncertainty about the causes and
the likelihood of such occurrences. These catastrophic global dis-
turbances warrant a higher priority for research than the local dis-
turbances to which so much attention has been given.

Population Growth

Like the role of natural resources, the role of population in
the standard neoclassical model is ripe for re-examination. The
assumption is that population and labor force grow exogenously like
compound interest. Objections arise on both descriptive and normative
grounds. We know that population growth cannot continue forever. Some
day there will be stable or declining population, either with high birth
and death rates and short life expectancies, or with low birth and death

rates and long life expectancies. As Richard Easterlin argues in his National Bureau book, there surely is some adaptation of human fertility and mortality to economic circumstances. Alas, neither economists nor other social scientists have been notably successful in developing a theory of fertility that corresponds even roughly to the facts. The subject deserves much more attention from economists and econometricians than it has received.

On the normative side, the complaint is that economists should not fatalistically acquiesce in whatever population growth happens. They should instead help to frame a population policy. Since the costs to society of additional children may exceed the costs to the parents, child-bearing decisions are a signal example of market failure. How to internalize the full social costs of reproduction is an even more challenging problem than internalizing the social costs of pollution.

During the past ten years, the fertility of the United States population has declined dramatically. If continued, this trend would soon diminish fertility to a level ultimately consistent with zero population growth. But such trends have been reversed in the past, and in the absence of any real understanding of the determinants of fertility, predictions are extremely hazardous.

The decline may be illustrated by comparing the 1960 and 1967 net reproduction rates and intrinsic (economists would say "equilibrium") rates of growth of the United States population. The calcula-

tions of Table 3 refer to the asumptotic steady-state implications of indefinite continuation of the age-specific fertility and mortality rates of the year, 1960 or 1967.

TABLE 3.

U. S. Population Characteristics in Equilibrium

	Intrinsic Growth Rate (% per year)	Net Reproduction Rate	Median Age
1960 fertility-mortality	2.1362	1.750	21-22
1967 fertility-mortality	0.7370	1.221	28
Hypothetical ZPG	0.0000	1.000	32

Should the trend of the 1960s continue, the intrinsic growth rate would become zero and the net reproduction rate 1.000 in the 1970s. Supposing that the decline in fertility then stopped, the actual population would grow slowly for another forty or fifty years while the inherited bulge in the age distribution at the more fertile years gradually disappeared. The asumptotic size of the population would be between 250 and 300 million.

One consequence of slowing down the rate of population growth by diminished fertility is, of course, a substantial increase in the age of the equilibrium population, as indicated in the third column of Table 3. It is hard to judge to what degree qualitative change and innovation have in the past been dependent on quantitative growth.

When our institutions are expanding in size and in number, deadwood
can be gracefully bypassed and the young can guide the new. In a
stationary population, institutional change will either be slower
or more painful.

The current trend in fertility in the U. S. suggests that, con-
trary to the pessimistic warnings of some of the more extreme anti-
growthmen, it seems quite possible that ZPG can be reached while
child-bearing remains a voluntary private decision. Government
policy can concentrate on making it completely voluntary, by ex-
tending the availability of birth control knowledge and technique
and of legal abortion. Since some 20% of current births are es-
timated to be unintended, it may well be that intended births at
present are insufficient to sustain the population.

Once the rate of population growth is regarded as a variable,
perhaps one subject to conscious social control, the neoclassical
growth model can tell some of the consequences of its variation. As
explained above, sustainable per capita consumption (growing at the
rate of technological progress) requires enough net investment to
increase the capital stock at the natural rate of growth of the
economy (the sum of the rate of increase of population and produc-
tivity). Given the capital/output ratio, sustainable consumption
per capita will be larger the lower the rate of population increase;
the capital-widening requirement is diminished.

This is, however, not the only effect of a reduction of the rate of population growth. The equilibrium capital-output ratio itself is altered. The average wealth of a population is a weighted average of the wealth positions of people of different ages. Over its life cycle the typical family, starting from low or negative net worth, accumulates wealth to spend in old age, and perhaps in middle years when children are most costly. Now a stationary or slow-growing population has a characteristic age distribution much different from that of a rapidly growing population. The stationary population will have relatively fewer people in the early low-wealth years, but relatively more in the late low-wealth years. So it is not obvious in which direction the shift of weights moves the average.

We have, however, estimated the shift, by a series of calculations described in Appendix C. Illustrative results are shown in Tables 4 and Figure 1. Evidently reduction in the rate of growth increases the society's desired wealths-income ratio. This means an increase in the capital-output ratio which increases the society's sustainable consumption per capita. [1]

On both counts, therefore, a reduction in population increase should raise sustainable consumption. We have essayed an estimate of the magnitude of this gain. In a ZPG equilibrium sustainable consumption per capita would be 9-10% higher than in a steady state of 2.1% growth corresponding to 1960 fertility and mortality, and somewhat more than 3% higher than in a steady state of 0.7% growth corresponding to 1967 fertility and mortality.

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[1]. Provided only that the change is made from an initial situation in which the net marginal productivity of capital exceeds the economy's natural rate of growth. Otherwise the increased capital-widening requirements exceed the gains in output.

These neoclassical calculations do not take account of the lower pressure of population growth on natural resources. As between the 1960 equilibrium and ZPG, the diminished drag of resource limitations is worth about one tenth of 1 percent per annum in growth of per capita consumption. Moreover, if our optimistic estimates of the ease of substitution of other factors of production for natural resources are wrong, a slowdown of population growth will have much more important effects in postponing the day of reckoning.

Is Growth Obsolete? We think not. Although GNP and other national income aggregates are imperfect measures of welfare, the broad picture of secular progress which they convey remains after correction of their most obvious deficiencies. At present there is no reason to arrest general economic growth to conserve natural resources, although there is good reason to provide proper economic incentives to conserve resources which currently cost their users less than true social cost. Population growth cannot continue indefinitely, and evidently it is already slowing down in the United States. This slowdown will significantly increase sustainable per capita consumption. But even with ZPG there is no reason to shut off technological progress. The classical stationary state need not become our utopian norm.

TABLE 4.

Illustrative Relationship of Sustainable per capita Consumption to Marginal Productivity of Capital and Capital/Output Ratio

(1)		(3)	(4)	(5)	(6)	(7)	(8)
Marginal Productivity of Capital		Ratio of Capital to GNP	Ratio of Capital to NNP	Index of NNP per capita	Index of consumption per capita		
					1960 pop. growth	1967 pop. growth	ZPG
Gross	Net of Depreciation						
R	$R - \delta$	μ'	μ	y	c	c	c
.09	.05	3.703	4.346	1.639	1.265	1.372	1.426
.105	.065	3.175	3.637	1.556	1.265	1.344	1.386
.12	.08	2.778	3.125	1.482	1.245	1.309	1.343
.15	.11	2.222	2.439	1.356	1.187	1.233	1.257

Notes: A Cobb-Douglas production function is assumed for GNP, with constant returns to scale, with an elasticity of output with respect to capital α of 1/3, and with the rate γ of labor-augmenting technological progress 3% per year. The depreciation rate δ is assumed to be 4% per year. GNP per capita Y is $ae^{\gamma t}k^{\alpha}$ and NNP per capita y is $Y - \delta k$ where k is the capital-labor ratio.

Column (3) Since $Rk = \alpha Y$, $\mu' = \frac{k}{Y} = \frac{\alpha}{R}$.

Column (4) $\mu = \frac{\mu'}{1 - \delta\mu'}$

Column (5) $y = (1 - \delta\mu')Y$. For the purpose of the index, $ae^{\gamma t}$ is set equal to 1.

Columns (6), (7), (8) $c = [1 - (n + \gamma)\mu]y$. Given $\gamma = .03$, $n + \gamma$ is .0513 for 1960, .0374 for 1967, .0300 for ZPG.

TABLE 5.

Desired Wealth/Income Ratios Estimated for Different Rates of Population Growth (and for Different Equivalent Adult Scales and Subjective Discount Rates)

Desired wealth/income ratio

Net Interest Rate	1960 Pop.	1967 Pop.		
R - δ	Growth (.021) μ	Growth (.007) μ	ZPG μ	
.05	-1.70	-1.46	-1.24	Teenagers 1.0
.065	0.59	0.91	1.16	Children 1.0
.08	2.31	2.70	2.90	Discount .02
.11	4.31	4.71	4.95	
.05	0.41	0.74	0.97	Teenagers 0.6
.065	2.36	2.75	3.00	Children 0.7
.08	3.74	4.16	4.41	Discount .01
.11	5.17	5.55	5.75	
.05	-1.17	-0.95	-0.75	Teenagers 0.7
.065	1.08	1.38	1.60	Children 0.6
.08	2.74	3.11	3.34	Discount .02
.11	4.61	4.98	5.18	
.05	-0.40	-0.15	0.02	Teenagers 0.0
.065	1.93	2.20	2.36	Children 0.0
.08	3.56	3.85	4.01	Discount .02
.11	5.20	5.47	5.61	

Notes: The desired wealth/income ratio is calculated for a given steady state of population increase and the corresponding equilibrium age distribution. It is an aggregation of the wealth and income positions of households of different ages. As explained in Appendix C it also depends on (a) the interest rate, (b) the typical age-income profile and the expected growth of incomes (γ = .03) (c) the rate of subjective discount of future utility of consumption, (d) the weights given to Teenagers (boys 14-20 and girls 14-18) and other children in household allocations of life-time incomes to consumption in different years. See Appendix C for further explanation.
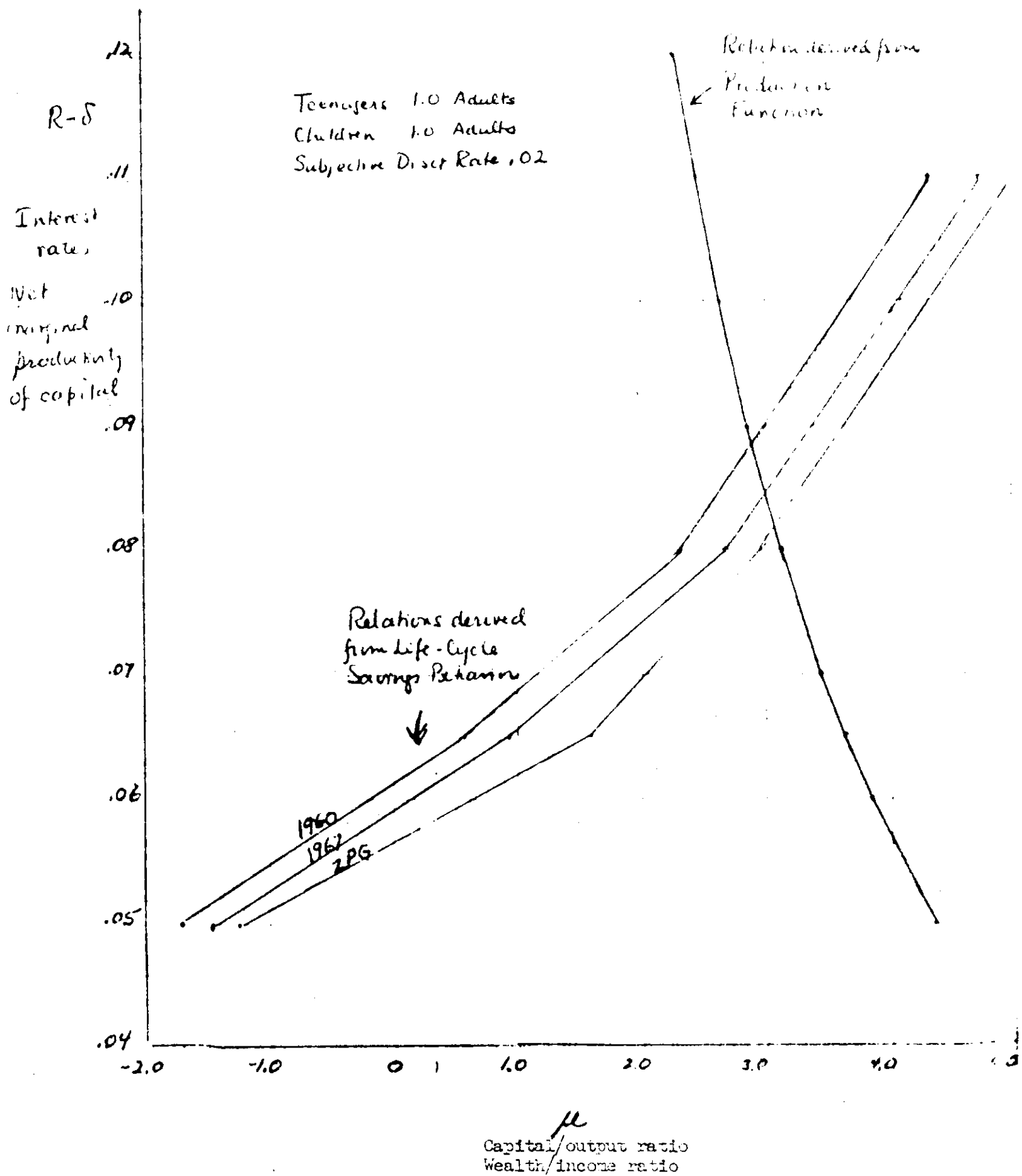
TABLE 6.

Estimated Equilibrium Capital/Output Ratios, and Per Capita Consumption Rates.

Population growth rate	Interest Rate $R - \delta$	Capital/Output Ratio μ	Consumption Index c	% Increase in c over 1960	Equivalent Asset Scale and Subjective Discount Rate
1960	.089	2.88	1.23		Teenagers - 1.0
1967	.085	2.99	1.30	5.62	Children - 1.0
ZPG	.082	3.07	1.34	9.04	Discount - .02
1960	.074	3.28	1.25		Teenagers - 0.
1967	.071	3.38	1.33	6.23	Children - 0.6
ZPG	.069	3.47	1.37	9.74	Discount - .01
1960	.084	3.00	1.24		Teenagers - 0.8
1967	.080	3.11	1.31	5.82	Children - 0.6
ZPG	.078	3.16	1.35	8.97	Discount - .02
1960	.077	3.22	1.25		Teenagers - 0.
1967	.074	3.28	1.32	6.42	Children - 0.0
ZPG	.073	3.33	1.36	9.99	Discount - .02

Note: Estimated by interpolation from Tables 4 and 5. See Figure 1.

Figure 1
Determination of Equilibrium Capital/Output Ratio and Interest Rate

Teenagers   1.0 Adults
Children   1.0 Adults
Subjective Disct Rate .02

$R - \delta$

Interest rates

Net marginal productivity of capital

Relations derived from Production Function

Relations derived from Life-Cycle Savings Behavior

1960
1962
2PG

μ
Capital/output ratio
Wealth/income ratio

APPENDIX A.

A Measure of Economic Welfare

The purpose of this appendix is to explain the Measure of Economic Welfare (MEW) introduced in the text. Conceptually it is a comprehensive measure of the annual real consumption of households. Consumption is intended to include all goods and services, marketed or not, valued at market prices or at their equivalent in opportunity costs to consumers. Collective public consumption is to be included, whether provided by government or otherwise; and allowance is to be made for negative externalities, such as those due to environmental damage and to the disamenities and congestion of urbanization and industrialization. Real consumption is estimated by valuing the flows. of goods and services at constant prices.

We distinguish Sustainable Welfare (MEW^S) from Actual Welfare (MEW^a). Sustainable MEW is the amount of consumption in any year that is consistent with sustained steady growth in per capita consumption at the trend rate of technological progress. MEW, whether sustainable or actual, can be expressed either in aggregate or in per capita terms. For obvious reasons set forth in the text, we regard the per capita measure as the more relevant one, a judgment that enters into the very definition of MEW^S.

Actual MEW excludes all final output actually devoted to capital replacement and accumulation. Sustainable MEW excludes the capital expenditures needed to sustain the capital-output ratio. It allows

for capital depreciation, for equipping new members of the labor force, and for increasing capital per worker at the trend rate of productivity change. MEW^s will be greater than MEW^a in years when the economy is investing more than these requirements, and smaller when it is investing less. In a neo-classical growth model, excess of MEW^s over MEW^a means that the capital/output ratio is rising, the economy is moving to a higher equilibrium growth path, and MEW^s is increasing faster than the trend rate of technological progress. An excess of MEW^a over MEW^s means the opposite.

We have not attempted to estimate a concept of "potential MEW" -- analogous to potential GNP -- which would correct for fluctuations in utilization of the labor force and the capital stock. Consequently comparisons of MEW, actual or sustainable, are best confined to periods of comparable utilization. The end points of our trial calculations, 1929 and 1965, are roughly comparable in this respect.

We are aiming for a consumption measure, but we cannot of course estimate how well individual and collective happiness are correlated with consumption. We cannot say whether a modern society with cars, airplanes, and television sets is really happier than the nation of our great-grandparents who lived without use or knowledge of these inventions. We cannot estimate the externalities of social interde-pendence, of which Veblen, Galbraith, and other social critics have complained. That is, we cannot tell to what degree increases in con-sumption are offset by displeasure that others are also increasing their consumption. Nor can we tell how much consumption is simply the relief of artificially induced cravings nurtured by advertising and sales effort.

In suggesting a consumption-oriented measure, we do not in any
way derogate the importance of the conventional national income ac-
counts. They are, of course, the chief and indispensable source of
our calculations, which are for the most part simply a rearrangement
of the data the Department of Commerce faithfully and skillfully pro-
vides. Gross National Product and Net National Product are measures
of output performance. As such, they are the relevant measures both
for short-run stabilization policy and for assessing the economy's
long-run progress as a productive machine.

Our purpose is different and suggests a different measure.
Consider, for example, the treatment of defense expenditure, which
rose from less than 1% of GNP in 1929 to 10% in 1965. The capacity
of the economy to meet this rise in defense demands, along with others,
certainly deserves to be counted in assessing its gains in productive
performance between the two dates. But we exclude defense expendi-
tures because they add to neither actual nor sustainable household
consumption. This exclusion does not charge the rise in
defense expenditures as an inevitable by-product of the growth of the
economy, nor does it imply any judgment as to their necessity or de-
sirability. It simply acknowledges that this component of GNP growth,
whatever its causes and consequences, does not enter via normal eco-
nomic processes into the consumption satisfactions of households.

We recognize that our proposal is controversial on conceptual and theoretical grounds and that many of the numerical expedients in its execution are dubious. Nevertheless, the challenge to economists to produce relevant welfare-oriented measures seems compelling enough to justify some risk-taking. We hope that others will be challenged, or provoked, to tackle the problem with different assumptions, more refined procedures, and better data. We hope also that further investigations will be concerned with the distribution, as well as the mean value, of a measure of economic welfare, an aspect we have not been able to consider.

In the remaining sections of this appendix we explain the details of the calculations presented in text Table 1. Section 1 concerns reclassification of expenditures reported in national income accounts to obtain a more comprehensive concept of consumption. This reclassification implies some adjustments in the capital accounts, presented in section 2. In section 3 we describe our imputations for consumption yielded by nonmarket activities, and in section 4 our adjustments for the disamenities of urban growth. Section 5 describes the final estimates, and section 6 contains some discussion of their reliability.

A.1. Reclassification of Final Expenditures

A.1.1. Government purchases

In the United States Income and Product Accounts, government purchases of goods and services are counted as final output and are not classified as consumption and investment. For our purposes, we need to classify

Defense expenditures have no direct value in household consumption. No reasonable nation purchases defense because its services are desired per se. The product of defense outlays is national security but it is clearly not true that our security has increased as the outlays rose a hundredfold from 1929 to 1965. Changes in international relations and in military technology have vastly multiplied the costs of providing a given level of security. Just as we count the fruits of scientific progress, managerial improvement, and mineral discovery when they make it easier for the nation to wrest its living from the environment, so we must count the results of deterioration in the nation's economic or political environment. This procedure does not blame the economy for unfavorable international political events any more than recording a reduction in food crops due to bad weather or a plague of locusts means that the agricultural economy has become any less efficient.

The final category, "intermediate goods and services" is clearest when the government is providing direct services or materials to business enterprises. It also includes more diffuse instrumental outlays: the costs of maintaining a sanitary and safe natural and social environment. There is no sharp dividing line between intermediate overhead expenditures and regrettables. Police protection, for example, might fall under either category.

A.1.2 Private Purchases.

We have also made some reclassifications of private expenditures:
(a) Personal business expenses and one-fifth of personal transporta-
tion expenses (an estimate of the fraction devoted to commutation)
are subtracted from consumption and regarded as intermediate or in-
strumental (Table A-16, line 2), (b) Educational and medical out-
lays are regarded as gross investments (Table A-16, line 4),
(c) All outlays for consumer durables, not just purchases of residences,
are treated as investments (Table A-16, line 3), (d) Imputations are
made for those services of consumer capital that are directly consumed
(Table A-16, line 5); these are described in section A.2.

A.2. Adjustments for Capital.

Conventional national income accounting limits investment to domestic
business investment and residential construction. Economists have come to
include a much wider group of expenditures in this category. Table A-2
gives a list of the conventional items and those added for our present
purposes, for the year 1958.

The three important accounting problems introduced by this treatment
of capital are (a) calculation of the net stock of wealth; (b) calcula-
tion of imputed services from capital to be added to consumption; (c) decompo-
sition of gross investment into capital consumption and net investment to
calculate sustainable MEW.

TABLE A-1. Reclassification of Government Purchases
of Goods and Services.

[Billions of dollars, 1958 prices]

Item	1929	1935	1945	1947	1954	1958	1965
1. Public Consumption	0.3	0.3	0.4	0.5	0.5	0.8	1.2
2. Public Investment, Gross	15.0	19.3	9.7	18.6	30.6	37.0	50.3
3. Regrettables	1.7	2.0	139.7	14.4	49.4	46.4	47.6
4. Intermediate Goods and Services	5.0	5.4	6.6	6.4	8.4	10.0	15.6
5. TOTAL Government Consumption and Investment	15.3	19.6	10.1	19.1	31.1	37.8	51.5
6. TOTAL Government Purchases	22.0	27.0	156.4	39.9	88.9	94.2	114.7

Notes: Based on current dollar figures for federal and state and local purchases of goods and services, NIP, Table 3.10, deflated by government purchases deflator, Table 8.1. Line 6 is also line 20 of NIP Table 1.2.

1. Consumption: postal service (line 52)
recreation (line 61)

2. Investment: one half atomic energy development (line 4)
education (line 16)
health and hospitals (line 21)
commerce, transportation, & housing (line 39)
conservation and development of resources (line 60)
agriculture (line 54)

3. Regrettables: national defense (line 2) less one half
atomic energy development (line 4)
space research and technology (line 6)
international affairs & finance (line 13)
veterans benefits and services (line 33)

4. Intermediate: everything else, including
general government (line 7)
sanitation (line 22)
civilian safety (line 28)

For years prior to 1954, NIP Table 3.10 is not available and the breakdowns were based on estimates by broad expenditure category.

TABLE A-2.   Items of Gross Investment, 1958

[Billions of dollars and percent]

Item

Conventional items:	Investment	Percent of Total
1. Business Investment	40.1	25.4%
2. Residential Construction	20.8	13.2
New items:		
3. Government Investment	37.0	23.5
4. Consumer Durables	37.9	24.0
5. Other Consumer Investments	19.6	12.4
6. Net Foreign Investment	2.2	1.4
Total	157.6	100.0%

Source:

line 1, NIP Table 1.2, line 8-line 14
line 2, NIP, Table 1.2, line 11
line 3, Table A-1 above, line 2
line 4, NIP, Table 1.2, line 3
line 5, NIP, Table 2.5, lines 42 plus 93, less 44.
line 6, NIP Table 1.2, line 6

A.2.1.   Net Stock of Wealth.

Most of the figures for components of wealth have been gathered from other sources. They are shown in Table A-3. The figures for Educational Capital and Health Capital have been constructed in part by us. The estimates of tangible capital, reproducible and nonreproducible, are from Goldsmith and Kendrick.[1]

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[1]. John Kendrick, Productivity Trends in the United States, Princeton for NBER, 1961.

TABLE A-3. Net Stock of Wealth, Public and Private

[Billions of dollars, 1958 prices]

Item	1929	1935	1945	1947	1954	1958	1965
1. Net Reproducible Capital	765.6	742.3	832.5	895.3	1186.6	1367.5	1676.2
2. NonReproducible Capital a)	299.0	276.1	245.9	262.2	299.9	335.4	392.4
3. Educational Capital	91.2	120.2	253.2	269.0	447.2	581.6	879.4
4. Health	7.2	28.7	44.5	49.5	74.8	89.5	121.2
5. Total	1163.0	1167.3	1376.1	1476.0	2008.5	2374.1	3069.2

Sources:

Lines (1) and (2) for 1929 to 1958 from Raymond Goldsmith, National Wealth of the United States in the Postwar Period, Princeton University Press, 1962, Tables A-1, A-2 and A-16. The value for 1965 is from John Kendrick's estimates presented in Statistical Abstract of the U. S., 1967, Tables 492 and 494. Figures for 1935 and 1965 are linear interpolations.

Line (3) is described in text.
Line (4) is deflated Health Expenditures, public and private, cumulated with an assumption of an exponential depreciation rate of 20 percent per annum. Public health expenditures are given in NIP table 3.10, line 21; private in NIP table 2.5, line 42.

a) Nonreproducible capital covers five categories, listed below with their relative importance in 1958.

Item	Share of Total Value of Nonreproducible Assets, 1958 [percent]
Agricultural Land	30.2
Residential Land	18.1
Nonresidential Land	32.2
Public Land	12.2
Net Foreign Assets	7.3
Total	100.0

The data on nonreproducible wealth are dubious. In principle, the increased value in constant prices of nonreproducible assets comes primarily through upgrading land from agricultural to non-agricultural uses.[1] In practice, given the nature of the estimates, some of the recorded increase may be due to improper deflation.

The value of educational capital is based on T. Schultz's estimates of the cost per pupil of attained education, valued at 1956 costs of each level of education. This assumes no technological change in education. We preferred to treat education in a similar way to other forms of wealth and to value it at replacement cost at constant prices rather than at constant 1956 costs. We therefore used Machlup's series of average cost per pupil to get an index of cost per pupil in constant prices. We then recalculated Schultz's figures to obtain the value of educational capital per member of the labor force.[2]

The value of health capital was constructed by cumulating deflated public and private medical health, and hospital expenditures. These were cumulated assuming exponential depreciation at 20 percent per annum.

A.2.2. Services from Wealth.

Having shifted some public and private expenditures from consumption to investment, we must impute consumption of services of those types of capital whose yield does not take the form of explicit factor earnings. Such imputations are made in the national accounts only for owner-occupied housing.

1/. See Raymond W. Goldsmith, The National Wealth of the United States in the Postwar Period, Princeton for NBER, 1962, p. 48, n. 2.

2/. Data are from Theodore Schultz, "Education and Economic Growth," in Social Forces Influencing American Education, N. B. Henry, ed., Chicago: 1961; Fritz Machlup, The Production and Distribution of Knowledge in the United States, Princeton, Princeton University Press, 1962.

For both consumer durable expenditures and government struc-
tures (excluding military), Juster has prepared estimates of capital
services.[1] We have used his estimates for services and these are
presented in Table A-4. It should be noted that this imputation is
not entirely appropriate since some of the imputed output is inter-
mediate (that is, used by business). On the other hand, his assumed
rates of return seem quite low and this low estimate may offset the
erroneous inclusion of some intermediate product.

We do not impute any consumption services to health or educational
capital. To the extent that health and education expenditures lead to
higher productivity, there is no need for further imputation. We make
the admittedly extreme assumption that no direct gains in satisfaction
are produced by these categories of wealth. Since they have been growing
faster than the other stocks, our assumption may lead to understatement
of the growth of welfare.

1/. F. Thomas Juster, Household Capital Formation and Its Financing,
    1897-1962, National Bureau of Economic Research, 1966, Appendix B.

TABLE A-4.   Imputed Services from Consumer Durables

and Civilian Government Structures

[Billions of dollars]

	1929	1935	1945	1947	1954	1958	1965
			Current Prices				
Imputed Net Rental							
Consumer	3.6	1.9	3.5	5.6	10.6	13.9	23.2
Government	0.4	0.5	1.8	2.8	3.8	5.0	6.3
Capital Consumption							
Consumer	6.2	4.2	7.9	12.2	21.7	26.9	44.9
Government	1.5	1.7	2.8	3.9	6.4	9.0	11.8
Total Services	11.7	8.3	16.0	24.5	42.5	54.8	86.2
			1958 Prices				
Consumer Services	24.9	17.8	22.1	26.7	37.2	40.8	62.3
Government Services	4.8	6.4	8.9	10.0	11.7	14.0	16.6
Total Services	29.7	24.2	31.1	36.7	49.0	54.8	78.9

Source: Figures in current prices are from Juster, op. cit., Appendix B,
Tables B-2 and B-4.   The constant price series is obtained by dividing
by the deflator for fixed investment.

The figures for 1965 were extrapolated from 1962 using data on
purchases and depreciation of consumer durables.

A.2.3. Capital Consumption and Net Investment.

In Table A-5 we show first in lines 1, 6, and 7 the national accounts figures for gross investment, capital consumption, and net investment. For our MEW we have, as explained above, broadened the concepts of capital and investment. Lines 5, 8, and 9 give estimates for the MEW concepts of gross investment, capital consumption, and change in capital stock. Capital consumption, line 8, is estimated from the wealth data of Table A-3 above.

In addition, we have estimated a new concept of net investment, called "net MEW investment." This is the amount of investment to be added to actual MEW to obtain sustainable MEW. Zero net MEW investment corresponds to that gross investment which would keep per capita consumption growing at the rate of technological progress. In the standard neoclassical growth model, with labor-augmenting technical progress and a constant rate of labor force participation, this is also the gross investment necessary to maintain a constant ratio of capital to the effective or augmented labor force and a constant ratio of capital to output. The conventional net investment needed for this purpose we call the growth requirement   (Table A-5, line 10). Net MEW investment (line 11) is change in capital stock less the growth requirement.

TABLE A-5. Gross and Net Investment in National Accounts (NIPA) and in Measure of Economic Welfare (MEW)

	1929	1935	1945	1947	1954	1958	1965
1. Gross Investment, NIPA	40.4	18.0	19.6	51.5	59.4	60.9	99.2
2. Government Purchases Reclassified as Investment for MEW	15.0	19.3	9.7	18.6	30.6	37.0	50.3
3. Consumer Purchases Reclassified as Investment for MEW							
a) consumer durables	16.7	11.5	12.3	26.2	35.5	37.9	60.9
b) education and health	6.5	6.3	9.1	10.4	15.3	19.6	30.1
4. Net Foreign Investment, NIPA and MEW	1.5	-1.0	-3.8	12.3	3.0	2.2	6.2
5. Gross Investment, MEW	80.1	54.1	46.9	119.0	143.8	157.6	246.7
6. Capital Consumption, NIPA	20.0	20.0	21.9	18.3	32.5	38.9	54.7
7. Net Investment, NIPA	20.4	-2.0	-2.3	33.2	26.9	22.0	44.5
8. Capital Consumption, MEW	39.3	53.4	33.6	69.1	67.7	66.2	147.4
9. Change in Capital Stock, MEW	40.8	0.7	13.3	49.9	76.1	91.4	99.3
10. Growth Requirement, MEW	46.1	46.7	65.8	-5.4	63.1	78.9	101.8
11. Net Investment, MEW	-5.3	-46.0	-52.5	55.3	13.0	12.5	-2.5

Sources:
Line 1. NIP Table 1.2, line 6.
Line 2. Table A.1, line 2.
Line 3a. NIP Table 1.1, line 3, deflated by the consumption deflator.
Line 3b. NIP Table 2.5, lines 42 plus 93 less 44, all deflated by consumption deflator, NIP Table 8.1, line 2.
Line 4. NIP Table 1.2, line 17.
Line 5. Sum of lines 1-4.

6. NIP Table 1.9, line 2, deflated by fixed investment deflator, NIP Table 8.1, line 7.
7. Line 1, minus line 6.
8. Line 5 minus line 9
9. Estimated on per annum basis from Table A-3.
10. Annual increase in capital stock necessary to keep up with trend growth of labor forces and productivity. See text.
11. Line 8 minus line 10, or line 5 minus (line 9 + line 10).

If NNP is a desirable measure of social income in a stationary economy, sustainable MEW is a natural analogue for a growing economy. [1] Indeed, in the special case of zero population growth and no technological change, sustainable MEW and NNP are identical. NNP, it will be recalled, is the amount of consumption that leaves the capital stock "intact." The reason for keeping capital intact in a stationary economy is that the same amount of consumption, in aggregate and per capita, will be available in future years. The reason for keeping the capital-output ratio intact in a growing economy is that per capita consumption will grow at the rate of technological progress.

An alternative concept of social income would be sustainable per capita consumption, which will be larger than sustainable MEW when there is technological progress. Per capita consumption can be sustained by technological advance even while the capital-output and capital-labor ratios steadily decline. With a production function that allows factor substitution, today's consumption standard could eventually be produced with a capital-labor ratio asymptotically approaching zero. During this process the marginal productivity of capital would steadily rise. Our proposed measure of social income is more austere and, we believe, more consonant with revealed social preference. We do not observe current generations consuming capital on the grounds that their successors will reap the benefits of technological progress.

A guiding principle for a definition of social income is the following. The social income is that amount of consumption that is

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[1]. See P. A. Samuelson, "The Evaluation of 'Social Income'," in Lutz and Hague, editors, The Theory of Capital, London: Macmillan, 1961.

consistent with the social valuation of investment at its current oppor-
tunity cost in terms of consumption. The social value of giving up
an extra dollar of current consumption in favor of capital accumu-
lation is the sum of the resulting increments to future consumption,
each discounted by the appropriate social discount rate. When this
value exceeds a dollar, investment is less than optimal and con-
sumption should be reduced, until lowered capital yield and in-
creased social discount rates combine to lower the value of invest-
ment to par. Similarly, when the stream of returns from a marginal
dollar of investment sums to less than a dollar, current investment
is too large and consumption too small. The amount of current con-
sumption at which the marginal social value of investing a dollar at
the expense of consumption is precisely a dollar may be regarded as
the social income. It follows that the optimal amount of MEW net
investment -- defined as social income less actual consumption -- is
zero.

How do sustainable MEW and NNP relate to this principle? Under
what conditions will these be the definitions of social income that
follow from the valuation principle given above? Sufficient con-
ditions can be presented formally. Let $c(t)$ be consumption per worker
at time t and $L(t)$ the size of the work force. We assume that the
labor force is a fixed proportion of the population; therefore $c(t)$ can
also be regarded as an index of per capita consumption. The labor
force L is growing exponentially at rate n. Labor-augmenting tech-
nical progress is occurring at rate γ, so $L(t)e^{\gamma t}$ is the effec-
tive labor force, which is growing at rate $g = n + \gamma$. Gross output per
worker is $e^{\gamma t}f(k)$ where k is the ratio of capital stock to effective

labor force $K/Le^{\gamma t}$ and k' is the rate of change of k. Capital depreciates at the exponential rate δ.

The equation relating consumption, output, capital, and investment at every moment of time is:

(A.1) $c(t) = e^{\gamma(t)}[f(k(t)) - (g+\delta)k(t) - k'(t)]$

Consider a feasible and efficient consumption plan: a sequence $c(t)$ for $t \geq 0$, feasible in the sense that it is consistent with (A.1) given the initial capital stock, $k(0)$, efficient in the sense that it would not be possible to increase any $c(t)$ without diminishing some other $c(t)$. We can then ask: What is the increase in per capita consumption at time θ that can be obtained by a unit reduction of per capita consumption at time 0 -- the present -- keeping the rest of the plan unchanged?

Let $r(t) = f'(k(t)) - \delta$, the net marginal productivity of capital at time t. Since the population is growing exponentially at rate n, the rates that transform per capita saving and investment today into per capita consumption in the future are $r(t) - n$; that is, a unit reduction of the rate of per capita consumption at time 0 will yield an increase of per capita consumption at time θ of $\exp\left[\int_0^\theta [r(t) - n]dt\right]$ if consumption rates at all other times before and after θ are unchanged. [1]

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[1]. The rate at which incremental saving at time t can increase k, the ratio of capital to effective labor, is $r(t) - g$. Over the interval $(0,\theta)$ continuous reinvestment of the proceeds of incremental saving at time 0 will compound the increase in k to $\exp\left[\int_0^\theta [r(t)-g]dt\right]$. The increase of the aggregate capital stock

1/. (Cont'd.)

will then be $L(0)e^{g\theta} \cdot \exp\left[\int_0^\theta [r(t)-g]dt\right] = L(0) \exp\left[\int_0^\theta r(t)dt\right]$.

This increment can be consumed during a small interval following time θ while leaving subsequent values of $k(t)$ at their original values, so that the initial consumption plan can be executed thereafter. Divided among the population $L(0)e^{n\theta}$ this gives an increment of per capita consumption of

$$\exp\left[\int_0^\theta [r(t)-n]dt\right] .$$

If the consumption plan corresponds to a neo-classical growth equilibrium, k and r are constants and per capita consumption is growing at rate γ . The marginal trade-off of later for earlier consumption is $e^{(r-n)\theta}$ and depends only on the intervening time θ .

We turn now to the other half of the story, the social valuation of increments of future consumption yielded by current saving. Suppose that society's intertemporal preferences, at any current date designated by 0 , can be described by a social welfare function

$U = \int_0^\infty u[c(t)]e^{-\rho t}dt$, where u is the one-period utility of consumption and ρ is the constant pure rate of time preference at which utility is discounted. Let the one-period utility function be of the form $A + Bc^{1-\alpha}$ so that marginal utility $u'(c) = (1-\alpha)Bc^{-\alpha}$, where α and $(1-\alpha)B$ are positive. Furthermore, the elasticity of marginal utility with respect to consumption is $u''c/u' = -\alpha$. Holding U constant, the marginal rate of substitution between per capita consumption rates at θ and 0 is $\dfrac{u'[c(0)]}{u'[c(\theta)]} = \left[\dfrac{c(0)}{c(\theta)}\right]^{-\alpha} e^{\rho\theta}$. Thus the slope of any indifference curve between $c(\theta)$ and $c(0)$ is $-e^{-\rho\theta}$ along the $45°$ ray and $-e^{(\rho + \alpha\gamma)\theta}$ along the ray $c(\theta) = c(0)e^{\gamma\theta}$. See Figure A.1.

Under these assumptions the basic condition that must be met in order that the social valuation of investment equal its cost in current consumption is equality of the two intertemporal substitution rates, the one reflecting production possibilities and the other social preferences. They must be equal for every time interval θ :

$$\left[\frac{c(0)}{c(\theta)}\right]^{-\alpha} e^{\rho\theta} = \exp\left[\int_0^\theta (r(t)-n)dt\right]$$

For a consumption path in equilibrium growth at rate γ , the condition reduces to

$$e^{(\rho + \alpha\gamma)\theta} = e^{(r-n)\theta}$$

This will be true for all θ provided that $\rho + \alpha\gamma = r-n$.

If this condition is met, as illustrated in Figure 1, the path of sustainable MEW -- per capita consumption growing at rate γ -- fulfills the basic principle for definition of social income.[1]

In the absence of technological progress and population growth, the condition is simply $\rho = r$. The path of NNP -- constant per capita and aggregate consumption -- meets the condition that the net marginal productivity of capital equal the pure social rate of time preference.

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[1]. The result can also be derived by explicitly maximizing U with respect to the $k'(t)$ given $k(0)$, using (A.1). The first order conditions are:

$$\int_t^\infty u'[c(v)]e^{\gamma v}\{f'[k(v)] - (g+\delta)\}e^{-\rho(v-t)}dv = e^{\gamma t}u'(c(t)) \quad \text{all } t \geq 0$$

Differentiating this with respect to t gives

$$-u'(c(t))e^{\gamma t}(r(t)-g)e^{-\rho t} = (\gamma-\rho)e^{(\gamma-\rho)t}u'(c(t)) + e^{(\gamma-\rho)t}u''[c(t)]c'(t)$$

Using $-\alpha = \frac{u''c}{u'}$ we have the general requirement that

1/. (Cont'd.)

$$r(t) - g = \rho-\gamma + \alpha \, \frac{c'(t)}{c(t)}$$

An equilibrium growth path will meet this condition if and only
if the constant value of k that characterizes it produces a
value of r such that

$$r-n = \rho + \alpha\gamma \ .$$

To summarize, social income is the amount society can consume
without short-changing the future. Thus social income refers to a
consumption path along which saving and investment are, according
to social valuations of their future yields, just worth their cost in
current consumption. Under special conditions this path may be one
with per capita consumption growing steadily at the rate of tech-
nological progress, and sustainable MEW is then the appropriate measure
of social income.   In our economy revealed social preference seems to
support our inference that the consumption plan is one of ever-growing
consumption per capita and our use of social valuations that are con-
sistent with steady growth.

Figure A.1

$$c(\theta) = c(0)e^{\gamma \theta}$$

$$c(\theta) = c(0)$$

OPPORTUNITY
LOCUS
(given Ω)

slope = $e^{(\rho + \alpha \gamma)\theta}$

slope = $e^{(n-n)\theta}$

slope = $e^{\rho \theta}$ *rho*

rho

INDIFFERENCE
LOCUS

$c(\theta)$
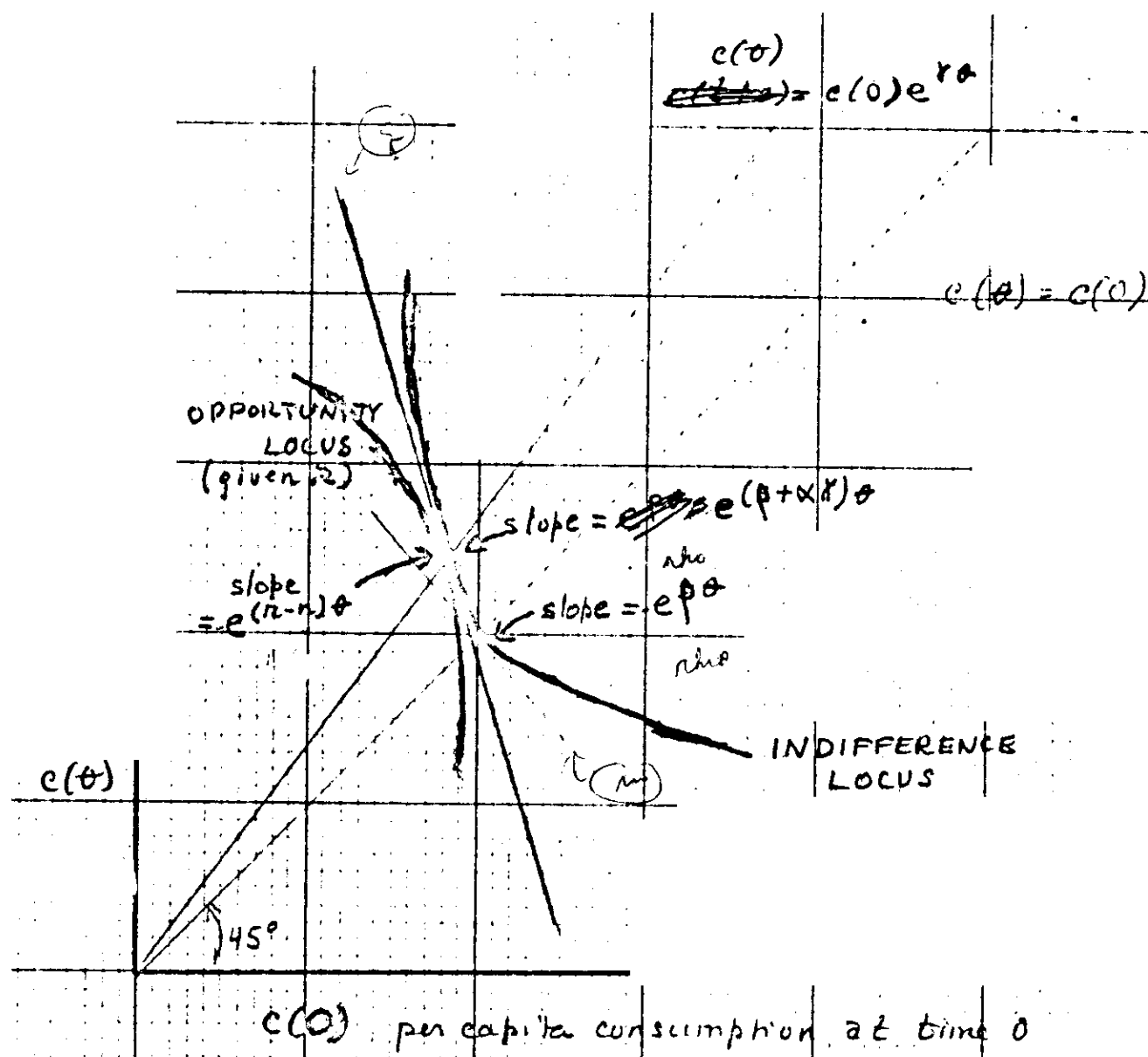
$c(M)$

$45°$

$c(0)$ per capita consumption at time 0

Illustration of Balanced Growth as Optimal
Consumption Plan. (ρ = pure rate of social time
preference; α = – elasticity of marginal utility;
γ = rate of technological progress.)

A.3. Imputation for Nonmarket Activities: Time Components of Consumption.

Only a fraction of a lifetime is spent in gainful employment, but it is that fraction alone that shows up in output and consumption as ordinarily measured. Leisure and nonmarket work grow steadily in importance, and their omission can bias downward estimates of trends of per capita consumption. Imputation of the consumption value of leisure and nonmarket work presents severe conceptual and statistical problems. Since the magnitudes are large, differences in resolution of these problems make big differences in overall MEW estimates.

A.3.1. Conceptual Issues.

Consider an individual dividing a fixed endowment of time R among gainful employment W, leisure L, and nonmarket productive activity H. From the earnings of his employment he purchases consumption C. Let v_t be the real wage, $v_t p_t^C$ the money wage, and p_t^C the price of market consumption goods, all for year t. These prices can be observed. Let p_t^L be the price of an hour of the consumption good leisure, and p_t^H the price of an hour's worth of the consumption good produced by home activity. These prices cannot be observed, and this is the source of the problem. Take all base period prices, v_o, p_o, p_o^C, p_o^L, p_o^H, to be one.

On the principle that the individual can on the margin exchange leisure or nonmarket activity for market consumption at the money wage $v_t p_t^C$, we can estimate the total money value of his consumption as $v_t p_t^C W_t + v_t p_t^C H_t + v_t p_t^C L_t$. But what did he get for his "money"? The

three components of consumption must be "deflated" by the relevant prices p_t^C, p_t^H, p_t^L . This gives an expression for real consumption

$$v_t W_t + \frac{v_t p_t^C}{p_t^H} H_t + \frac{v_t p_t^C}{p_t^L} L_t$$

Since real consumption in time zero is by definition R , the consumption index is:

(A.4) $\qquad v_t \frac{W_t}{R} + \frac{v_t p_t^C}{p_t^H} \frac{H_t}{R} + \frac{v_t p_t^C}{p_t^L} \frac{L_t}{R}$

The basic issue is whether the consumption prices of nonmarket uses of time have (a) risen with wage rates, or (b) risen with the prices of market consumption goods. On the first assumption, an hour not sold on the market is still an hour, the same in 1955 as in 1929. The only gains in consumption that can be credited on this account are the reductions in hours of work. On the second assumption, an hour not sold in the market has increased in consumption value the same as an hour worked, namely by the increase in the real wage.

In our numerical estimates below we have calculated three variants:

A) $\quad p_t^H = p_t^L = v_t p_t^C$. The index (A.2) is then $1 + (v_t - 1)\dfrac{W_t}{R}$.

This is the most conservative alternative.

B) $\quad p_t^H = p_t^C$; $p_t^L = v_t p_t^C$. The index is $1 + (v_t - 1)\dfrac{W_t + H_t}{R}$.

C) $\quad p_t^H = p_t^L = p_t^C$. The index is $1 + (v_t - 1) = v_t$.

(C) is the most optimistic alternative.

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The essential question is whether nonmarket activities have shared in the technical progress that has raised real wages. If this progress has been time-augmenting, not simply work-augmenting, then the optimistic alternative is correct. But if technology has increased solely the effectiveness of on-the-job work, the **pessimistic** alternative is correct.

The alternatives can be shown diagrammatically if we confine ourselves to two instead of three uses of time. In Figure A.2, the horizontal axis measures leisure and the vertical axis market consumption. The line $R_o C_o$ represents the opportunity locus in the base period; its slope is -1, on the convention that the base period real wage is scaled at unity. The point x_o represents the individual's choice. In period t the real wage has increased to v_t, the slope of the new opportunity locus is $R_o C_t$, and the selected point is x_t. According to the **pessimistic** interpretation, the gain in welfare, measured in market consumption, is approximated by the vertical difference between the two lines $R_o C_o$ and $R_o C_t$, measured either up from x_o or down from x_t. The individual's time has not increased, and he gains from the higher real wage only in the degree that he works.

The optimistic interpretation is that technological progress has augmented his time, so that in terms of effective leisure and consumption the opportunity locus has shifted outward to $R_t C_t$. The real wage per effective hour is unchanged, although it has increased in terms of natural

Figure A.2

Alternative Interpretations of Welfare Gains accompanying Wage Increases.
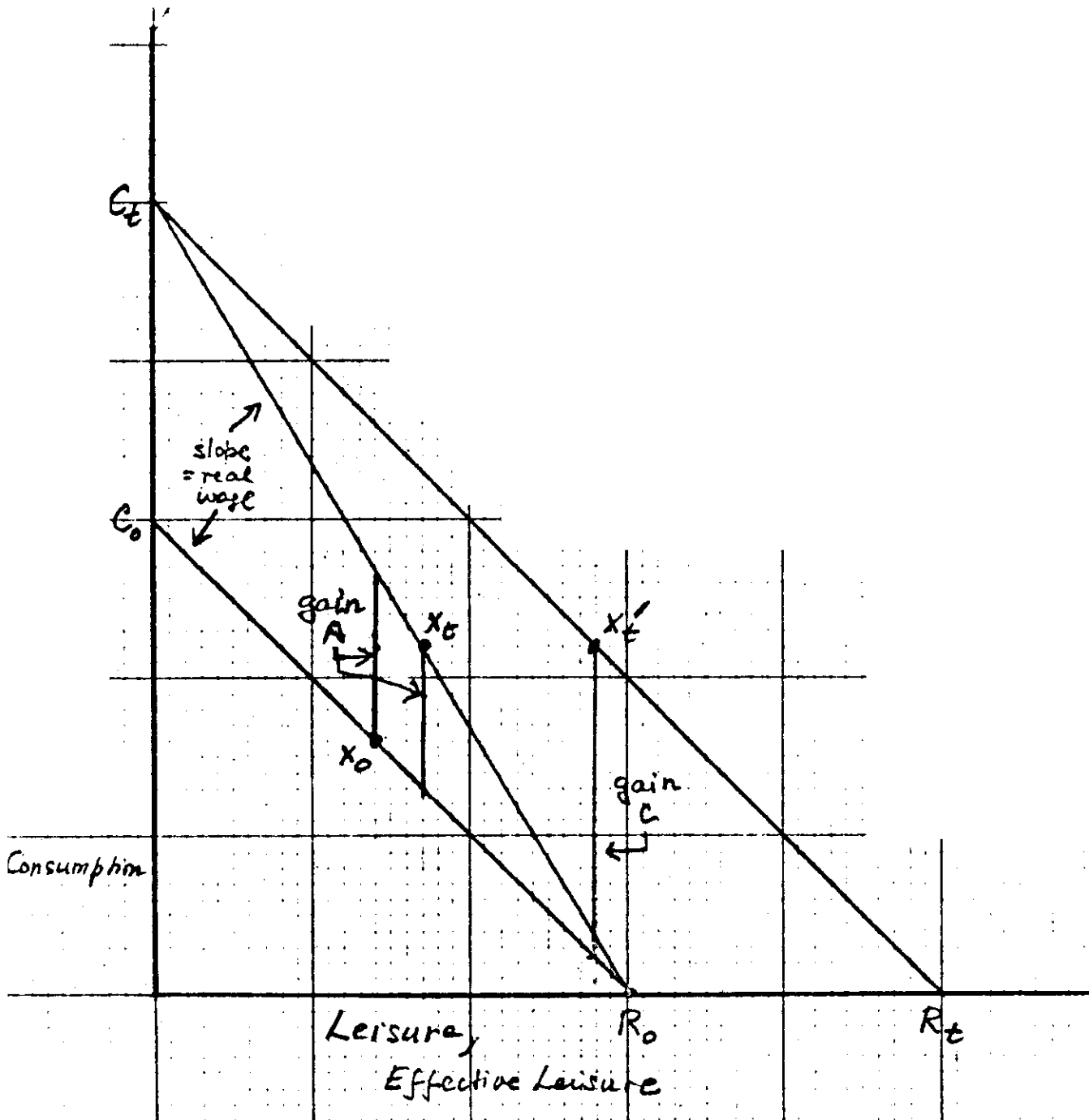
hours. The point x_t is, in terms of effective leisure, really x_t'.
The increment in welfare is approximated by the vertical difference
between the parallel lines R_oC_o and R_tC_t, and is independent of
the amount of time the individual works in either period.

Formally, let the individual maximize $U(v_tW_t, h_tH_t, \ell_tL_t)$ [1] subject
to $W_t + H_t + L_t = R$ where h_t and ℓ_t are augmentation indexes for
household production and leisure, with $h_o = \ell_o = 1$. The first order
conditions are $v_tU_1 = h_tU_2 = \ell_tU_3 = \lambda_t$.

If (W_o, H_o, L_o) is the maximizing decision at time zero and
(W_t, H_t, L_t) at time t, what is the measure of the change in welfare?
The change in utility can be linearly approximated as

$$U_1(v_tW_t - W_o) + U_2(h_tH_t - H_o) + U_3(\ell_tL_t - L_o)$$

$$= [U_1(W_t - W_o) + U_2(H_t - H_o) + U_3(L_t - L_o)]$$

$$+ [U_1(v_t-1)W_t + U_2(h_t-1)H_t + U_3(\ell_t-1)L_t]$$

The first of the two terms is the substitution effect, which is approxi-
mately zero because with $v_o = h_o = \ell_o = 1$, $U_1 = U_2 = U_3 = \lambda_o$ and
$W_t + H_t + L_t = W_o + H_o + L_o = R$. The second term is the income effect,
the gain in utility we seek. Dividing by U_1, we convert the utility
gain into its equivalent in market consumption:

$$(v_t-1)W_t + (h_t-1)H_t + (\ell_t-1)L_t$$

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[1]. We have assumed that work does not enter directly into the utility
function. We do not consider complications that may arise if work is
a direct source of satisfaction or pain, Nor do we see any way to
measure the marginal utility of work.

Expressed as a ratio of base period consumption R , this gives the results cited above: (A) if $h_t = \ell_t = 1$, (B) if $h_t = v_t, \ell_t = 1$, (C) if $h_t = \ell_t = v_t$.

Nonmarket Activity. Housework is not directly productive of satisfaction, but rather yields a range of end-products (meals, healthy children, gardens, etc.). Given the increase in household equipment and consumer durables, it would be surprising if nonmarket activities did not share in at least part of the advances in technologies that have raised productivity in the market economy.

The proper deflation of housework would be a base-weighted price of the bundle of home-produced services. In the absence of such an index, the closest measure is the deflator for the service component of consumption expenditures in the national accounts. This is compared with the total consumption deflator and the wage index in Table A-6.

TABLE A-6. Rise in Three Price Indexes, 1929-1965

	Ratio: 1965 to 1929	Average Annual Growth Rate
Consumption Deflator	1.97	1.9%
Service Deflator	2.06	2.0
Wage Index	4.65	4.3

Source: NIP Table 8.1 and Table A-11 below.

It is clear that the price deflators for services and for consumption as a whole moved together over this period, while the wage index rose more than twice as fast. Table A-7 gives the growth of price indexes for important categories of consumption related to housework.

TABLE A-7. Rise in Prices for Various Household Services, 1929-1965

	Ratio: 1965 to 1929	Average Annual Growth Rate
Transportation	2.12	2.1%
Cleaning	2.06	2.0
Domestic Service	3.39	3.4
Barbershops	3.03	3.1
Medical Care	2.71	2.8
Purchased Meals & Beverages	2.35	2.4

Source: NIP Table 8.6. Note that the index of domestic service is an index of costs rather than a proper output price index.

Leisure poses a deeper problem. To the extent that time itself is the final good -- daydreaming, lounging, resting -- then the conservative interpretation is indicated. But if leisure time is one among several inputs into a consumption process, then it may well have been augmented by technological progress embodied in the complementary inputs -- television, boats, cars, sports equipment, etc.

A.3.2. Measurement.

We are not aware of any reasonably comprehensive estimates of the use of time over the period 1929 to 1965. Data on the average workweek are available and are used below. Table A-8 gives the results of a large sample survey conducted in 1954. We are doubtful about its reliability, but at present we have no choice but to base our estimates on this survey.

TABLE A-8. Use of Time, 1954.

[Average hours per day, between 6 a.m. to 11 p.m.]

Item	Men	Women
Work	6.0	1.5
Cost of Work	1.4	0.7
Personal care	0.6	0.9
Housework	2.2	6.7
Leisure	6.8	7.1

Source: A Nationwide Study in Living Habits, cited in de Grazia, On Time Work and Leisure.

Note: Leisure includes time at restaurant, tavern; at friend's or relative's home; in games, sports, church; recreation at home; reading; and sleep during this 17 hour period.

According to this survey leisure time amounts to about 47.6 hours per week for men and 49.7 hours per week for all surveyed women. We will regard personal care and cost of work as instrumental maintenance items and exclude them from consumption. The important item other than leisure is housework, which takes 46.9 hours a week for women and 15.4 hours per week for men.

Table A-9 makes a breakdown of the population age 14 and over [1] by five time occupations for different years.

TABLE A-9. Principal Occupation of Population, 14 and Over, Various Years

[Millions of Persons]

	Total Population	Employed	Unemployed	Keeping House	School	Other
1929	88.0	47.9	1.5	28.1	6.0	4.5
1935	95.5	42.5	10.6	30.3	6.6	5.5
1945	106.7	64.3	1.0	27.8	4.8	8.8
1947	108.8	59.6	2.4	32.4	6.4	8.0
1954	117.7	64.3	3.6	33.9	6.3	9.6
1958	123.1	66.5	4.7	34.2	7.5	10.2
1965	137.6	74.6	3.5	35.6	11.1	12.8

Source: Economic Report of the President, 1967, Table B-20 for employed and unemployed. Other series from U. S. Department of Commerce, Statistical Abstract, various years; U. S. Department of Commerce, Historical Statistics of the U.S. Since series are not always compatible, some adjustments have been made to link them. For 1929 and 1935, the last three columns are estimated from data on female population and employment, school enrollment, and population over 65 years, with the total constrained to equal total population.

---

[1]. Why do we exclude children under 14? Because the market value of their time is very low, not because we undervalue the joys of childhood.

Table A-10 estimates the average hours of leisure and nonmarket activity for the five groups of the population described in Table A-9. Table A-11 shows the wage rates applicable to each group.

TABLE A-10. Hours of Leisure and Nonmarket Work, Person Over 14.

[Hours per Week]

Year	Employed & Unemployed			Keeping House			School			Other		
	L	NM	Tot	L	NM	Tot	L	NM	Tot	L	NM	Tot
1929	39.4	15.4	54.8	49.7	46.9	96.6	50	13	63	50	10	60
1935	45.5	15.4	60.9	49.7	46.9	96.6	50	13	63	50	10	60
1945	43.1	15.4	58.5	49.7	46.9	96.6	50	13	63	50	10	60
1947	45.7	15.4	61.1	49.7	46.9	96.6	50	13	63	50	10	60
1954	47.6	15.4	63.0	49.7	46.9	96.6	50	13	63	50	10	60
1958	48.6	15.4	64.0	49.7	46.9	96.6	50	13	63	50	10	60
1965	48.1	15.4	63.5	49.7	46.9	96.6	50	13	63	50	10	60

L = Leisure hours;   NM = Nonmarket hours;   Tot = Total hours

Source: Hours of leisure are obtained by using the benchmark estimates for 1954 and then making estimates using data on average hours worked for other years. Thus the number of leisure hours for any year is obtained by subtracting from 47.6 (the number of hours of leisure for 1954) the difference in hours between the reference year and 1954. Hours data from Kendrick, op. cit., Table A-X and A-VI. It is assumed that unemployed workers had the same number of hours of leisure and nonmarket work as employed workers. Further, it is assumed that nonmarket activity stayed the same since 1929. Those keeping house were assumed to have no change in the total number of hours available in 1954 (96.6 per week). Arbitrary numbers were chosen for students and other persons.

TABLE A-11. Manufacturing Wage Rate and Wage Rate for Different

Groups in Population

[Current Dollars Per Hour]

Year	Employed	Unemployed	Females	Under 20 Years Old	Over 65 Years Old	Wage Index (1958=1.00)
1929	0.56	0.56	0.34	0.19	0.49	0.2654
1935	0.54	0.54	0.32	0.18	0.47	0.2559
1945	1.016	1.016	0.61	0.35	0.89	0.4815
1947	1.217	1.217	0.73	0.42	1.06	0.5768
1954	1.78	1.78	1.07	0.61	1.55	0.8436
1958	2.11	2.11	1.27	0.72	1.84	1.000
1965	2.61	2.61	1.57	0.89	2.28	1.237

Source: Basic wage data from Economic Report of President and Historical
Statistics of the U. S. The basic figure is average hourly earnings
in manufacturing, which is the only series available back to 1929.
(This differs slightly but not appreciably from the ratio of total
labor income to Kendrick's manhour estimate). Wage rates for females,
for those in labor force under 20, and for those in labor force over
65 years old are calculated as a fraction of the manufacturing wage
rate (these numbers being 0.58, 0.34, and 0.81). The data used to
calculate the fractions are median income of persons who are year-
round, full-time workers. Thus the ratio of median incomes of fe-
males to males is 4,560/7,814 = 0.58. (Data given in U. S. Department
of Commerce, Current Population Reports, Consumer Income, Series P-60,
No. 66, December 23, 1969, p. 90.)

The wage index is constructed from the data for employed workers and
takes 1958 as the base.

The general problem of valuation of housework and leisure time was discussed above. In addition, there are some special problems:

(1) Unemployment: In general, time is to be valued at its opportunity cost, the wage rate. Should the unemployed be treated as having zero wage? Clearly this is not the proper treatment for the frictionally or voluntarily unemployed, whose opportunity cost should be close to the market wage rate. On the other hand, during the Great Depression, most unemployed persons could not have obtained work at anywhere near the prevailing wage. Our compromise is to treat the unemployment as involuntary and thus assign a zero price to the normal working hours of the unemployed. On the other hand, we continue to value their leisure time at the going wage. 1/

(2) Keeping house: The majority of those keeping house are women, and we thus choose the average hourly earnings for women as the proper valuation.

(3) School: Since those in school are primarily under age 20, we use the wage for that age group as the proper valuation of school time.

(4) "Other": The final category is "other persons," primarily retired. For this group, we choose the wage rate for persons over 65.

1/. An alternate imputation is to value all time of unemployed workers at zero. For the depression year 1935, this lowers our final estimate of MEW (B variant) by ten percent. It makes very little difference for movements over the entire period.

A-34

Finally in Table A-12 we calculate the total value of leisure, nonmarket activity, and the sum which we call the "time component" of MEW. Column (1) of Table A-12 gives the current dollar value of the three series. For the reasons given above, two alternative constant dollar values are calculated for both leisure and nonmarket activity, one using the wage rate as deflator, the other using the consumption price index. Column (2) of Table A-12 shows the result if price deflation is used, while column (3) shows the result of using the wage deflator.

We feel that price deflation is probably superior for nonmarket activity, but that for leisure there is no general presumption. We have, therefore, proceeded with the three variants shown in Table A-12.

(A) <u>Variant A</u> It is assumed that there has been no technological change in the time component and deflation is therefore by wage rates.

(B) <u>Variant B</u> This is a hybrid, in which it is assumed that technological change has been occurring at the average rate for nonmarket activity, but that no technological change has taken place in leisure. For this variant, leisure is deflated by the wage index, while nonmarket activity is deflated by the consumption deflator.

(C) <u>Variant C</u> It is assumed that technological change has been occurring at the average rate for leisure and nonmarket activity and both are therefore deflated by the consumption deflator.

For most of our discussion below and in the text, our preferred variant is B.

TABLE A-12. Value of Leisure and Nonmarket Activity

[Billions of Dollars].

A-12(a) Leisure		
(1)	(2)	(3)
Current Prices	Deflated By Consumption Deflator	Deflated By Wage Rates

	(1) Current Prices	(2) Deflated By Consumption Deflator	(3) Deflated By Wage Rates
1929	90.1	162.9	339.5
1935	102.7	231.3	401.3
1945	217.0	331.8	450.7
1947	269.3	345.6	466.9
1954	441.4	477.2	523.2
1958	554.9	554.9	554.9
1965	775.5	712.8	626.9

A-12(b) Nonmarket Activity

	(1)	(2)	(3)
1929	47.4	85.7	178.6
1935	48.5	109.2	189.5
1945	99.7	152.4	207.1
1947	124.3	159.6	215.5
1954	195.6	211.5	231.9
1958	239.7	239.7	239.7
1965	321.4	295.4	259.8

A-12(c) Total, Time Component

	(1)	(2)	(3)
1929	137.5	248.6	518.1
1935	151.2	340.5	590.8
1945	316.7	484.2	657.8
1947	393.6	505.2	682.4
1954	637.0	688.7	755.1
1958	794.6	794.6	794.6
1965	1,096.9	1,008.2	886.7

Notes to Table A-12:

Col (1) computes for each group total hours per week times total persons times hourly wage rate times 52 and sums across all groups. Data are from Tables A-9, A-10 and A-11.

Col (2) deflates col (1) by consumption deflator.

Col (3) deflates col (1) by index of wage rate (last column of Table A-11).

A.4. Disamenities and Externalities

In principle those social costs of economic activity that are not internalized as private costs should be subtracted in calculating our measures of economic welfare. The problems of measurement are formidable, and we have been able to do very little toward their solution.

One type of social cost not recorded in the national income accounts is the depletion of per capita stocks of environmental capital. Nonappropriated resources such as water and air are used and valued as if they were free, although reduction in the per capita stocks of these resources diminishes sustainable consumption in future. If we had estimates of the value of environmental capital, we could add them to the national wealth estimates of Table A-3 and modify our calculations of MEW net investment accordingly. We have not been able to make this adjustment, but given the size of the other components of wealth, we do not believe it would be significant.

Some unrecorded social costs diminish economic welfare directly rather than through the depletion of environmental capital. The disamenities of urban life come to mind: pollution, litter, congestion, noise, insecurity, buildings and advertisements offensive to taste, etc. Failure to allow for these negative consumption items overstates not only the level but very possibly the growth of consumption. The fraction of the population exposed to these disamenities has increased, and the disamenities themselves may have become worse.

We have attempted to measure indirectly the costs of urbanization. Our measure relies on the assumption that people can still choose resi-

dential locations, urban or nonurban, high density or low density.
Individuals and families on the margin of locational decisions will,
we would expect, require higher incomes to live in densely populated
cities than in small towns and rural areas. Urban areas do have
higher wage rates and incomes. We interpret this differential as
the "disamenity premium" compensating for living in less pleasant
surroundings. From the estimated per capita income premium and the
locational distribution of the population we can compute an aggregate
correction and observe its changes over time.

Urban income differentials also reflect, of course, technological
productivity advantages. The uncorrected national accounts claim all
the gains in productivity associated with urbanization; our correction
removes some of them on the ground that they merely offset disamenities.
We would not be justified in cancelling out income differentials which are
still inducing migration. We have therefore allowed for observed
migration and estimated an equilibrium zero-migration differential.—
We have also attempted to standardize for other factors affecting locational de-
cision besides density and for other sources of income differences.

Our estimates are based on a single cross-section, the 1960 census.
Consequently we do not know whether the disamenity premium has increased
over time. We have simply applied the 1960 premium to population dis-
tributions 1929-1965.

The unit of observation is the county. It was desired to include
sparsely populated areas, and this would not be possible with cities or

standard metropolitan statistical areas. The basic data are from the U. S. Department of Commerce City and County Data Book, 1960 . Regressions were run separately across the counties in each of four states, and in three New England states as a unit. This procedure was followed because we thought that pooling across states and regions would introduce additional sources of variation in locational decision and income choice and obscure the density effects we were seeking to estimate.

The regressions are reported in Table A-13. The dependent variable is the log of median family income for the county. The relevant coefficients are α_1, α_2, and α_4 , referring to county population, density, and percent of county population in urban areas. The other regression variables are included to allow for other sources of income differences. Table A-14 summarizes the regression results for the population variables and shows the values used in the MEW calculations carried out in Table A-15.

The disamenity adjustment is not insubstantial: in 1965 it amounts to about 8 percent of average family disposable income. If the population were completely urbanized, the adjustment would be about one-third of income. But the correction as a fraction of income has not risen since 1929. Although the population has become more urban and more dense, incomes have grown relative to the disamenity differential.

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<u>TABLE A-13.</u> <u>Preferred Equation for County Regression</u> (Continued)

Area	Dependent Variable (log of median Income)	α_0 Constant	α_1 log of Population	α_2 log of Density	α_3 Migration Rate	α_4 log of % Urban Population	α_5 Population Negro	α_6 Population over 65	α_7 log of Median years of Schooling
Mass, RI, Conn.		7.9*** (17.1)	.039** (1.89)	-.020* (.92)	.00045 (.24)	.0595* (.93)	-.0089 (-1.0)	-.017 (.021)	.182* (.73)
N.H.		2.85*** (1.8)	.093* (.94)	-.087* (1.2)	-.00079 (-.58)	-.073** (1.5)	-.031* (1.0)	-.031* (.93)	1.86*** (4.21)
New York		7.7*** (15.3)	.010 (.65)	.035*** (2.93)	.0012*** (.25)	.035** (1.3)	-.011*** (2.9)	-.011** (1.9)	.44*** (3.0)
Wisconsin		7.74*** (15.7)	-.036** (1.3)	.091*** (3.1)	.0029*** (2.6)	.035*** (3.1)	-.010 (0.6)	-.020*** (2.7)	.383*** (2.5)
Indiana		7.15*** (22.7)	-.0014 (.06)	.065*** (2.7)	.0017*** (2.4)	.0173** (1.7)	-.0072** (1.5)	-.020*** (4.6)	.413*** (4.4)

t = Statistics in parentheses
* = Significant at 75% confidence level
** = Significant at 90% confidence level
*** = Significant at 99% confidence level

TABLE A-14. Disamenity Estimates.

Area	Total Population Effect $\alpha_1 + \alpha_2$	Urbanization Effect α_4
Mass, RI, Conn.	.019	.059
N.M.	.006	-.073
New York	.045	.035
Wisconsin	.055	.035
Indiana	.064	.017

Values used in
Estimates

Elasticity of
income with
respect to: .06   .04

Disamenity per
unit change of income
1958 prices: 1.75 [a]   3.75 [b]

[a] The coefficient is $1.75 of average household income (1958 prices) per one million of population. This is derived as 1.75 = .06 (5421/180.7) (1.0/1.029), where 5421 = median family income in the sample states, 180.7 is population of U. S. in millions, 1.0 and 1.029 are consumer deflators for 1958 and 1960, respectively.

[b] The coefficient for urbanization is $3.75 of average household income per percentage point rise in average urbanization. This is derived as 3.75 = .04 (5421/56.2) (1.0/1.029), where 56.2 is average urbanization and all other figures are described in [a] above.

FIGURE A-3: MOVEMENTS IN PER CAPITA NNP
AND PER CAPITA SUSTAINABLE MEW, 1929-65
[1958 prices]
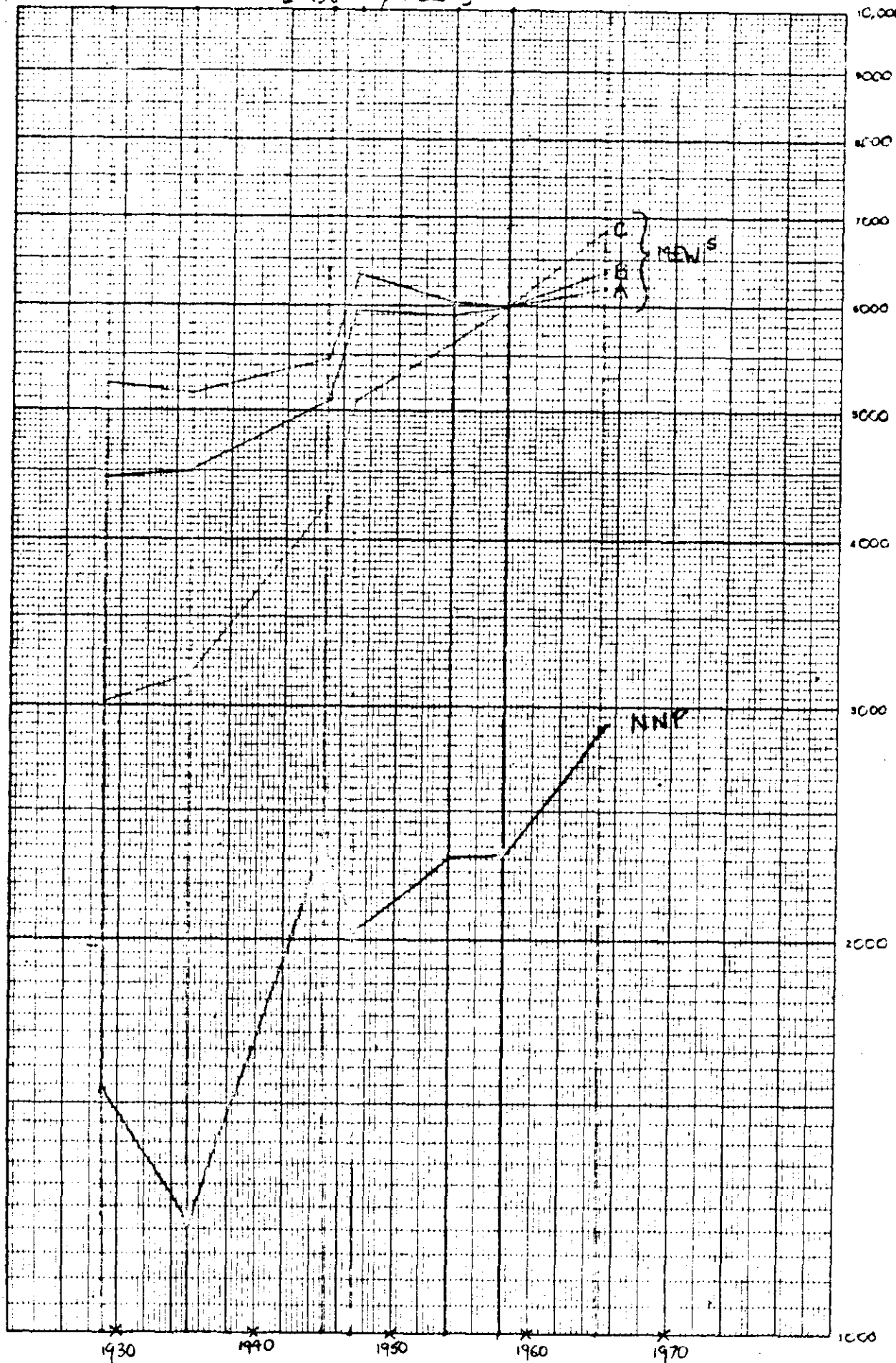
A.5 Estimates of MEW.

We now assemble the components of MEW in Table A-16, which is
the same as text Table 1. We also show in Table A-17 a reconciliation
of MEW and GNP. Table A-18 shows growth rates of NNP and of the
three variants of MEW^S. These four series are plotted in Figure A.3.

MEW looks quite different from NNP. It is roughly twice as large.
Our preferred variant of MEW^S -- variant B, which deflates nonmarket
activity by the consumption price index and leisure by the wage rate --
has grown somewhat more slowly than NNP, 2.3 percent per annum com-
pared with 3.0 percent. The more optimistic variant C has risen faster
than NNP. Even the most conservative estimate of MEW^S, variant A,
shows progress, though only at a rate of 0.5 percent per year.

The modifications of the national accounts which make the most
difference are the omissions of regrettables and the imputations for
leisure and nonmarket work.

The net MEW investment rate was negative before the second world
war and mainly positive since. Since 1945 sustainable MEW has, in the
main, exceeded actual MEW. We have been investing enough to move the
economy to a higher consumption path.

TABLE A-16. Measures of Economic Welfare, Actual and Sustainable

[billions of dollars, 1958 prices]

		1929	1935	1945	1947	1954	1958	1965
1.	Personal Consumption, NIPA	139.6	125.5	183.0	206.3	255.7	290.1	397.7
2.	Private Instrumental Expenditures	-10.3	-9.2	-9.2	-10.9	-16.4	-19.9	-30.9
3.	Durable Goods Purchases	-16.7	-11.5	-12.3	-26.2	-35.5	-37.9	-60.9
4.	Other Household Investment	-6.5	-6.3	-9.1	-10.4	-15.3	-19.6	-30.1
5.	Services of Consumer Capital Imputation	24.9	17.8	22.1	26.7	37.2	40.8	62.3

			1929	1935	1945	1947	1954	1958	1965
6.	Imputation for Leisure	B	339.5	401.3	450.7	466.9	523.2	554.9	626.9
		A	339.5	401.3	450.7	466.9	523.2	554.9	626.9
		C	162.9	231.3	331.8	345.6	477.2	554.9	712.8
7.	Imputation for Nonmarket Activities	B	85.7	109.2	152.4	159.6	211.5	239.7	295.4
		A	178.6	189.5	207.1	215.5	231.9	239.7	259.8
		C	85.7	109.2	152.4	159.6	211.5	239.7	295.4

		1929	1935	1945	1947	1954	1958	1965
8.	Disamenity Correction	-12.5	-14.1	-18.1	-19.1	-24.3	-27.6	-34.6
9.	Government Consumption	.3	.3	.4	.5	.5	.8	1.2
10.	Services of Government Capital - Imputation	4.8	6.4	8.9	10.0	11.7	14.0	16.6

			1929	1935	1945	1947	1954	1958	1965
11.	Total Consumption = Actual MEW	B	548.8	619.4	768.8	803.4	948.3	1035.3	1243.6
		A	641.7	699.7	823.5	859.3	968.7	1035.3	1208.0
		C	372.2	449.4	649.9	682.1	902.3	1035.3	1329.5
12.	MEW Net Investment		-5.3	-46.0	-52.5	55.3	13.0	12.5	-2.5
13.	Sustainable MEW	B	543.5	573.4	716.3	858.7	961.3	1047.8	1241.1
		A	636.4	653.7	771.0	914.6	981.7	1047.8	1205.5
		C	366.9	403.4	597.4	737.4	915.3	1047.8	1327.0

TABLE A-16. (Continued)

[billions of dollars, 1958 prices]

			1929	1935	1945	1947	1954	1958	1965
14.	Population		121.8	127.3	140.5	144.7	163.0	174.9	194.6
15.	Actual MEW per capita (dollars)	B	4506	4866	5472	5552	5818	5919	6391
		A	5268	5496	5861	5938	5943	5919	6208
		C	3056	3530	4626	4714	5536	5919	6832
16.	Per Capita MEW^a, Index 1929 = 100	B	100.0	108.0	121.4	123.2	129.1	131.4	141.8
		A	100.0	104.3	111.3	112.7	112.8	112.4	117.8
		C	100.0	115.5	151.4	154.3	181.2	193.7	223.6
17.	Sustainable MEW per capita (dollars)	B	4462	4504	5098	5934	5898	5991	6378
		A	5225	5135	5488	6321	6023	5991	6195
		C	3012	3169	4252	5096	5615	5991	6819
18.	Per Capita MEW^a, Index 1929 = 100	B	100.0	100.9	114.3	133.0	132.2	134.3	142.9
		A	100.0	98.3	105.0	121.0	115.3	114.7	118.6
		C	100.0	105.2	141.2	169.2	186.4	198.9	226.4
19.	Per capita NNP -- Dollars		1945	1205	2401	2038	2305	2335	2897
	1929 = 100		100.0	78.0	155.4	131.9	149.2	151.1	187.5

Sources:

Line 1. NIP, Table 1.2, line 2.
Line 2. NIP, Table 2.5, line 52 (personal business) plus one fifth of line 60 (transportation), deflated by consumption deflator, NIP Table 8.1, line 2.
Line 3. NIP, Table 1.1, line 3 deflated by consumption deflator, NIP Table 8.1, line 2.
Line 4. NIP, Table 2.5, lines 42 plus 93 less 44, all deflated by consumption deflator, NIP, Table 8.1, line 2.
Line 5. Table A-4.
Line 6. Table A-12a: B column 3, A column 3, C column 2.
Line 7. Table A-12b: B column 2, A column 3, C column 2.
Line 8. Table A-15.
Line 9. Table A-1, line 1.

Sources: (Continued)

Line 10. Table A-4..
Line 11. Sum of lines 1-10.
Line 12. Table A-5, line 11.
Line 13. Line 10 plus line 11.
Line 14. Economic Report of the President, 1971, Table C-21, p. 221.
Line 15. Line 11 divided by line 14.
Line 17. Line 13 divided by line 14.
Line 19. NNP (NIP, Table 1.9) divided by (GNP deflator (NIP, Table 8.1)
          times population (Table A-15, line 4).

TABLE A-17. Gross National Product and MEW

[billions of dollars, 1958 prices]

	1929	1935	1945	1947	1954	1958	1965
1. Gross National Product	203.6	169.5	355.2	309.9	407.0	447.3	617.8
2. Capital Consumption, NIPA	-20.0	-20.0	-21.9	-18.3	-32.5	-38.9	-54.7
3. Net National Product, NIPA	183.6	149.5	333.3	291.6	374.5	408.4	563.1
4. NIPA Final Output Reclassified as Regrettables & Intermediates							
a) Government	-6.7	-7.4	-146.3	-20.8	-57.8	-56.4	-63.2
b) Private	-10.3	-9.2	-9.2	-10.9	-16.4	-19.9	-30.9
5. Imputations for items not included in NIPA:							
a) Leisure	339.5	401.3	450.7	466.9	523.2	554.9	626.9
b) Nonmarket Activity	85.7	109.2	152.4	159.6	211.5	239.7	295.4
c) Disamenities	-12.5	-14.1	-18.1	-19.1	-24.3	-27.6	-34.6
d) Services of public & private capital	29.7	24.2	31.0	36.7	48.9	54.8	78.9
6. Additional Capital Consumption	-19.3	-33.4	-11.7	-50.8	-35.2	-27.3	-92.7
7. Growth Requirement	-46.1	-46.7	-65.8	+5.4	-63.1	-78.9	-101.8
8. Sustainable MEW	543.6	573.4	716.3	858.6	961.3	1047.7	1241.1

Sources: Line 1, NIP, table 1.2, line 1.
Line 2, Table A-5, line 6.
Line 3, Line 1, minus line 2.
Line 4a, Table A-1, line 3 plus line 4.
Line 4b, Table A-16, line 2.
Line 5a, Table A-16, line 6.
Line 5b, Table A-16, line 7.
Line 5c, Table A-16, line 8.
Line 5d, Table A-4.
Line 6, Table A-5, line 9 minus line 6.
Line 7, Table A-5, line 10.
Line 8, Sum of lines 3-7, equal to Table A-16, line 13.

TABLE A-18. Rates of Growth of Different Measures

[Average compound growth rate, percent per year]

	1929-47	1947-65	1929-65
Total:			
NNP	2.6	3.6	3.1
MEW-A	2.2	1.6	1.9
MEW-B	2.8	2.0	2.4
MEW-C	4.0	3.3	3.6
Per Capita:			
NNP	1.4	2.0	1.7
MEW-A	1.2	0.0	0.6
MEW-B	1.7	0.5	1.1
MEW-C	2.3	1.6	2.3
Population	0.96	1.65	1.30

Source: Tables A-16 and A-17.

A.6   Reliability of the Estimates.

In national accounting, reliability cannot be calculated like statistical sampling error but only judged, for the most part subjectively, by those familiar with the data and the adjustments made in them. We have attempted to estimate very roughly the reliability of our measure of MEW and of its components. These judgments are presented in Table A-19.

We have used as a benchmark the reliability of the Gross National Product estimates, which we call (for reference) Low Error.[1] An item with "Medium Error" is one with a percentage error we feel to be about order of twice the percentage error of the GNP. High error is about five times the percentage error of GNP. "Very high error" is about ten times the percentage error of GNP.

The sources of unreliability lie both in the data (especially in the case of the time components of MEW) and in the concepts used (such as the proper deflator for leisure or the proper regression for calculating the disamenity premium). There are no independent estimates of comparable totals, as is sometimes the case in the income and product accounts. Totals, therefore, have all the unreliabilities that their components in combination contribute.

We must in all candor recognize that in moving away from the conventional accounting framework, we must accept sizable losses in the precision of the estimates.

_____

1/. Although no official estimate of the unreliability of GNP exists in the United States, the official estimate in the U. K. is that three percentage points either way includes a 90 percent confidence interval. (See Central Statistical Office, National Accounts Statistics, Sources and Methods, edited by Rita Maurice, pp. 42, 52), The Central Statistical Office, London, 1969.

TABLE A-19. Reliability of the Estimates of MEW

Item	Reliability
Consumption Expenditures in National Accounts	Low Error
Corrections for:	
Instrumental Expenditures	Medium Error
Capital Consumption	High Error
Growth Requirement	High Error
MEW Net Investment	Very High Error
Imputations for:	
Capital Services	High Error
Leisure	Very High Error
Nonmarket Activity	Very High Error
Disamenity	Very High Error
Totals:	
GNP	Low Error
MEW, excluding time component	Medium Error
MEW, with time component	High Error

Source: Authors' judgment.

APPENDIX B. Natural Resources

B.1. The Role of Natural Resources in Economic Growth.

In this appendix we consider the importance of natural resources in measured economic growth. In comparison with the usual neo-classical growth model, the laws of production are more complex. There are not simply constant returns to scale in capital and labor. The easiest way to view the problem is to assume a constant-returns-to-scale aggregate production function of the form

$$(B.1) \qquad Y = F(A_K K, \; A_L L, \; A_R R)$$

where Y is output, and K, L, and R are the services from capital, labor, and natural resources, respectively. All technological change is assumed to be factor augmenting, and A_i is the augmentation level of factor i.

In general, resources might be renewable and augmentable like capital, or exhaustible like stocks of minerals. But we shall confine ourselves to the case typified by "land," where the stock is constant -- neither augmentable or destructible --and the services are proportional to the stock.

We can take the logarithmic derivative of (1) to obtain:

$$(B.2) \qquad \hat{Y} = \xi_K(\hat{A}_K + \hat{K}) + \xi_L(\hat{A}_L + \hat{L}) + \xi_R(\hat{A}_R + \hat{R})$$

where hats over variables represent proportional rates of growth and ξ_i is the elasticity of output with respect to factor i.

Since our main interest is the movement of per capita quantities, we define y as per capita income Y/L, k as capital per head K/L, and r as land per head, R/L. From (2) we derive

$$\hat{y} = \hat{Y} - \hat{L} = \hat{A} + \xi_K(\hat{K} - \hat{L}) + \xi_R(\hat{R} - \hat{L}) + (\xi_K + \xi_R + \xi_L - 1)\hat{L}$$

where $\hat{A} = \hat{A}_K \xi_K + \hat{A}_L \xi_L + \hat{A}_R \xi_R$.

On the assumption of constant returns to scale, the sum of the elasticities of the three factors is unity. If $\hat{L}$ is the constant n, then $\hat{r} = \hat{R} - \hat{L} = -n$, and we have

$$(B.3) \qquad \hat{y} = \hat{A} + \xi_K \hat{k} - \xi_R n$$

and

$$(B.4) \qquad \hat{k} = \frac{sy}{k} - n$$

The production function (B.1) can be converted to the intensive form

$$y = A_L f(a_k k, a_r r) = A_L F\left(\frac{A_K K}{A_L L}, 1, \frac{A_R R}{A_L L} \right)$$

Balanced growth could occur with constant elasticities ξ_i, constant rates of technical progress, and a constant capital-output ratio k/y. The balanced growth rate is obtained by letting $\hat{k} = \hat{y}$ in (B.3). It is $\frac{\hat{A} - \xi_R n}{1 - \xi_K}$. The drag due to resource limitation is indicated by the second term in the numerator, as well as by the possibility that ξ_K is smaller than it would be in a two-factor economy.

The share of natural resource owners in national income appears to have fallen over time. This trend is not compatible with balanced growth, and there are several possible interpretations of it. One is the following combination of circumstances: the elasticity of substitution resources for the other two factors taken jointly is greater than one, and the _effective_ quantity of resources per effective worker $a_r r$ is declining. This implies that the elasticity of output with respect to resources, ξ_R, is falling, and therefore that the drag on growth is progressively diminishing.

A second interpretation is quite the opposite: the elasticity of substitution is less than one, but effective resources per effective worker are growing, thanks to the speed of resource-augmenting progress.

A third possible mechanism is a shift in demand away from resource-intensive goods, as a result either of income or of price effects. This mechanism cannot be easily described in a one-sector aggregative model. But price-induced shifts of demand are similar in effect to price-induced shifts of factor proportions. A high elasticity of substitution will lower the income shares of resource-owners. Inelasticity of demand for resource-intensive products with respect to income growth has the same qualitative effects as rapid land-augmenting progress.

To the central question -- how important are natural resources in measured growth? -- we seem to get an unambiguous answer: less important than they were. Table B-1 from Denison indicates that the share of land declined from about 9 percent to 3 percent from 1900 to 1950.[1] Denison concludes that

[1]. Edward F. Denison, _The Sources of Economic Growth in the United States_, (p. 30), Committee for Economic Development, 1962.

while land slowed down the growth rate .11 percent per annum for the
period 1909-1929, this drag was only .05 percent for 1929-57 and
would fall slightly more for the next twenty years.[1] In subsequent work, Denison
has also examined the extent to which differences in supplies of
land and natural resources can account for differences in productivity and
growth between the United States and Western European countries. He
finds the differences negligible.[2]

A closer look at specific products which are resource-intensive
confirms the general suspicion that resources have not been a drag.
In a careful study of the relative costs and prices of major categories
of resource-intensive goods, Barrett and Morse   conclude that, with
the exception of forestry products, none appears to have become rela-
tively more scarce than goods in general.[3] They examine reasons for
this paradox and show that the most important reason is pervasive tech-
nological change. Moreover, in those resource-using industries where
technology has not come to the rescue of scarcity, substitution of other
goods has been significant (substitution away from lead and zinc, from
forestry products, from animal power in agriculture).[4]

---

[1]. Edward F. Denison, The Sources of Economic Growth in the United States,
    (p. 270), Committee for Economic Development, 1962.

[2]. Edward F. Denison, Why Growth Rates Differ, Brookings, 1967, Chapter 14.
    The difference ranges between 0.5 and 0.6 percent of per capita
    national income, Harold J. Barnett and Chandler Morse, Scarcity and
    Growth, Johns Hopkins Press, 1963, p. 185.

[3]. Harold J. Barnett and Chandler Morse, Scarcity and Growth, Johns
    Hopkins Press, 1963, Part III. The other broad sectors were
    agriculture, extractive industries, and minerals.

[4]. "A rough calculation based on Btu's of mineral fuel indicates that
    if the United States today has to rely upon work animals for its
    'horsepower', the feed would require 15 to 30 times as many acres
    of cropland as are in use in the country." Harold J. Barnett and
    Chandler Morse, Scarcity and Growth, Johns Hopkins Press, 1963,
    p. 185.

TABLE B-1. SHARES OF FACTORS IN NATIONAL INCOME

Period	National Income	Labor	Land	Reproducible Capital Goods					
				Total	Nonfarm residential structures	Other structures and equipment	Inventories	U.S. holdings of private assets abroad	Less: Foreign holdings of U.S. private assets
1909-13	100.0	69.5	8.9	21.6	3.3	13.9	4.6	.4	.6
1914-18	100.0	67.0	8.8	24.2	3.5	15.3	5.3	.4	.3
1919-23	100.0	69.5	7.0	23.5	3.4	14.8	4.7	.8	.2
1924-28	100.0	69.7	6.4	23.9	4.3	14.6	4.3	.9	.2
1929-33[1]	100.0	69.2	6.2	24.6	4.5	15.3	4.2	1.0	.4
1934-38[1]	100.0	70.4	5.6	24.0	3.6	15.6	4.3	.8	.3
1939-43[1]	100.0	72.1	4.9	23.0	2.8	15.5	4.3	.6	.2
1944-48[1]	100.0	74.9	4.0	21.1	2.2	14.6	3.9	.5	.1
1949-53	100.0	74.5	3.4	22.1	2.5	15.4	3.8	.5	.1
1954-58	100.0	77.3	3.0	19.7	3.0	13.1	3.0	.7	.1
1909-58[1]	100.0	71.4	5.8	22.8	3.3	14.9	4.2	.6	.2
1909-29	100.0	68.9	7.7	23.4	3.7	14.6	4.8	.6	.3
1929-58[1]	100.0	73.0	4.5	22.5	3.1	15.0	3.9	.7	.2

1. For 1930 through 1940 and 1942 through 1946 these represent interpolated distributions, not the actual distribution for those dates. See text.

Source: Reproduced from Denison, The Sources of Economic Growth in the United States, op. cit., p. 30.

B.2. Simulations of Three-Factor Production Functions

Our brief review of historical tendencies in resource industries has led us to conclude tentatively that natural resources have not become an increasing drag on economic growth. One possible explanation for this result is that technology allows ample means for substituting away from increasingly scarce natural resources.

In an attempt to make this speculation more concrete, we have studied several three-factor aggregate production functions. Although two-factor (labor-capital) production functions have been widely studied, there does not appear to be comparable work on three-factor (labor-capital-land) functions. Moreover, the only analytical results available are for production functions with constant partial elasticities of substitution between different factors. Consequently, our first step was to examine different functional forms and parameter combinations to see which seemed to exhibit plausible behavior. The final choice between the simulations was on the basis of a comparison of the simulated results with the "revised stylized facts" of growth reviewed above.

Parameters

Four functional forms were tested:

(PF1) $\quad Y = [\alpha_1(A_K K)^{-\rho} + \alpha_2(A_L L)^{-\rho} + \alpha_3(A_R R)^{-\rho}]^{-\frac{1}{\rho}}$

(PF2) $\quad Y = [\alpha_1\left\{(A_K K)^{\frac{1}{4}}(A_L L)^{\frac{3}{4}}\right\}^{-\rho} + \alpha_2(A_R R)^{-\rho}]^{-\frac{1}{\rho}}$

(PF3) $\quad Y = [\alpha_1\left(\left\{\beta_1(A_K K)^{\frac{1}{2}} + \beta_2(A_L L)^{\frac{1}{2}}\right\}^{\frac{1}{2}}\right)^{-\rho} + \alpha_2(A_R R)^{-\rho}]^{-\frac{1}{\rho}}$

(PF4) $\quad Y = [\alpha_1\left(\left\{\beta_1(A_K K)^{-1} + \beta_2(A_L L)^{-1}\right\}^{-1}\right)^{-\rho} + \alpha_2(A_R R)^{-\rho}]^{-\frac{1}{\rho}}$

The first one is a general three-factor production function with Constant Elasticity of Substitution (CES). The others are two-stage CES functions, in which production depends on two factors, resources and a capital-labor composite. In PF2 the capital-labor composite is a Cobb-Douglas function of capital and labor, with assumed elasticities of 1/4 for labor and 3/4 for capital. In PF3 and PF4 the composite is itself a CES function of the two "neo-classical" factors, with different elasticities of substitution between them. Unlike PF1, the two-stage functions imply a different partial elasticity of substitution between capital and labor from that between resources and the other two inputs.

The assumptions about the partial elasticities can be summarized as follows:

Specification	Elasticity Between K and L	Elasticity Between (K,L) and R
PF1	$1/(1+\rho)$	$1/(1+\rho)$
PF2	1	$1/(1+\rho)$
PF3	2	$1/(1+\rho)$
PF4	1/2	$1/(1+\rho)$

The parameter values tested in simulations were as follows:

$\rho = -9/10, -1/2, -1/3, 1$

$g_{A_L} = 0, .015, .03$ rate of labor-augmenting progress

$g_{A_K} = 0, .015, .03$ rate of capital-augmenting progress

$g_{A_R} = 0, .015, .03$ rate of resource-augmenting progress

The numerical specifications were completed with the following parameters:

$$\alpha_1 = 0.9 \qquad\qquad s = \text{net savings rate } \frac{\Delta K}{Y} = 0.1$$

$$\alpha_2 = 0.1 \qquad\qquad g_L = \text{natural growth rate of labor} = 0.01$$

$$\beta_1 = 0.25 \qquad\qquad g_R = \text{growth rate of resource input} = 0.0$$

$$\beta_2 = 0.75$$

All values were indexed at 100 at time $t = 0$.

Altogether there were 405 specifications, differing in the form of the function (PF1-PF4) and in the numerical values of their parameters. Each case was simulated for 300 "years." The results were compared with the following stylized facts:

> Factor shares are labor 0.73, capital .22, resources .05. (Denison, The Sources of Economic Growth in the U.S., op. cit.)
> Capital growth exceeds output growth by 1% per year.
> Output growth is 3.5% per year.
> The marginal product of capital is constant at .15.

Simulations were scored by their conformity to these "facts." Two scoring procedures were used.

The first was based on an arbitrarily weighted sum of squared deviations of simulated results from the facts:

$$
\begin{aligned}
(\text{B.5}) \quad & (\text{L share} - 0.73)^2 + (\text{K share} - .22)^2 \\
& + 2(\text{R share} - .05)^2 + 3(g_K - g_Y) - (-.01)]^2 \\
& + 10(g_Y - .035)^2 + 0.2(\text{MPK} - .15)^2
\end{aligned}
$$

For each simulation, this sum was computed for each period and its minimum value found. The minimum value was Score I for the simulation. The lower the score, the more acceptable the simulation.

The second scoring technique consisted of seeing which of ten individual criteria were met in the year 100 of the simulation. Score II was simply the number of criteria met, a maximum of 10. The criteria were:

$$(i) \quad (g_K - g_Y) \quad \text{in} \quad [-.02, .005]$$

$$(ii) \quad (g_{MPL} - g_Y) \quad \text{in} \quad (-.01, .01)$$

$$(iii) \quad g_{MPK} \quad \text{in} \quad [.02, .02]$$

$$(iv) \quad g \quad \text{(share of labor)} \geq 0$$

(B.6)

$$(v) \quad \text{share of labor in} \quad [.6, .8]$$

$$(vi) \quad g(\text{share of } K) \quad \text{in} \quad (-.005, .005)$$

$$(vii) \quad \text{share of } K \quad \text{in} \quad (.15, .30)$$

$$(viii) \quad (\text{share of } R) \leq 0$$

$$(ix) \quad \text{share of } R \quad \text{in} \quad [.02, .10]$$

$$(x) \quad g_Y \quad \text{in} \quad [.03, .04]$$

Conditions (v), (vii), (ix), (i), and (x) in (B.6) are analogous to the first five terms in (B.5) in that order.

Results:

The two scoring functions are quite consistent. Score I ranged from .001183 to more than 3.0. The fifty-one lowest scores, ranging from .001183 to .003998 are analyzed below. None of the 405 cases scored 10 on the second test; ten scored 9. All ten of these cases are among the fifty-one cited above and listed in Table B-2. Other summary compilations appear in Tables B-3 through B-6.

Two fairly definite conclusions emerge from these simulations. The elasticity of substitution between resources and the capital-labor composite is greater than one in all 51 cases. Secondly, the partial elasticity of substitution between K and L is greater than one in the top seven cases, and equal to one (Cobb-Douglas) in 35 of the next cases. Only one out of the 102 substitution elasticities in these 51 cases is less than unity.

The findings relating to the rates of labor- and capital-augmenting technical change are somewhat clouded since in the Cobb-Douglas case factor-augmenting change is indistinguishable from Hicks-neutral (separable) technical change. There is, however, some reason to favor an estimate of g_{A_L} of .03 and of g_{A_K} of 0 . Of the sixteen cases in Table B-1 which are not Cobb-Douglas, fifteen have $(g_{A_K}, g_{A_L}) = (0, .03)$. Of the thirty-five Cobb-Douglas cases, twenty-six were such that $\frac{1}{4} g_{A_K} + \frac{3}{4} g_{A_L}$ was in the range $[2\frac{1}{8}, 2-\frac{5}{8}]$.

No conclusions are possible regarding the growth rate of resource-augmenting change. In all cases effective resources grow less rapidly than effective-capital plus -effective-labor; therefore with $\sigma_{(K,L),N}$ greater than unity the share of resources declines. If higher rate of g_R had been chosen, this conclusion might have been reversed.

TABLE B-2.

Fifty-One Best Scoring Simulations

PF	$\sigma_{(K,L),R} = \frac{1}{1+\rho}$	$\sigma_{K,L}$	g_{A_R}	g_{A_K}	g_{A_L}	Score I	PF	$\sigma_{(K,L)R}$	$\sigma_{K,L}$	g_{A_R}	g_{A_K}	g_{A_L}	Score I
1	1.5	1.5	0	0	.03	.001183	1	1.5	1.5	.015	0	.03	.002209
(1,3)	2	2	0	0	.03	.001250	2	2	1	.03	.015	.03	.002272
1	1.5	1.5	.03	0	.03	.001283	2	1.5	1	.015	0	.03	.002285
3	1.5	2	0	0	.03	.001303	2	1.5	1	0	.015	.03	.002302
(1,3)	2	2	.015	0	.03	.001325	2	1.5	1	0	.03	.015	.002346
3	10	2	.015	0	.03	.001344	2	1.5	1	.015	.015	.015	.002392
(1,3)	2	2	.03	0	.03	.001456	1	10	10	.03	0	.03	.002407
2	2	1	.03	0	.03	.001516	2	2	1	.015	.015	.03	.002441
1	10	10	0	0	.03	.001531	2	1.5	1	.03	.03	.015	.002480
3	10	2	0	0	.03	.001535	2	2	1	.015	.015	.015	.002759
2	1.5	1	.03	0	.03	.001559	2	2	1	0	.015	.03	.002779
2	2	1	0	0	.03	.001634	2	10	1	.03	.015	.03	.002795
2	10	1	.03	.03	.015	.001642	2	1.5	1	.015	.015	.03	.003123
2	1.5	1	.015	.03	.015	.001646	2	1.5	1	.03	.03	.03	.003155
2	10	1	.015	.03	.015	.001688	2	10	1	.015	.015	.03	.003288
2	10	1	.015	0	.03	.001704	2	10	1	.015	.015	.015	.003360
2	1.5	1	0	0	.03	.001719	2	1.5	1	0	.015	.015	.003462
2	2	1	.015	.03	.015	.001723	2	2	1	0	.015	.015	.003589
2	2	1	.03	.03	.015	.001732	4	1.5	1/2	.015	0	.015	.003630
1	10	10	.015	0	.03	.001753	2	1.5	1	.015	0	.015	.003634
2	2	1	0	.03	.015	.001799	2	10	1	0	.015	.015	.003883
3	1.5	2	.03	0	.03	.001828	2	1.5	1	0	.03	.03	.003907
2	2	1	.015	0	.03	.001872							
2	10	1	0	.03	.015	.001887							
2	1.5	1	.03	.015	.03	.001975							
2	10	1	0	0	.03	.001994							
3	10	2	.03	0	.03	.002125							
2	1.5	2	.015	0	.03	.002147							
2	10	1	.03	0	.03	.002171							

TABLE B-3. Distribution of Fifty-One Lowest Scores by Elasticity of
Substitution Between Capital-Labor and Resources

$\sigma_{(K,L),R}$	Number
.5	0
1.5	21
2	14
10	17

TABLE B-4. Distribution by Production Function

	$\sigma_{K,L}$	Number
PF1	$\sigma_{(K,L),R}$	9[*]
PF2	1	35
PF3	2	9[*]
PF4	1/2	1

* (In three cases PF1 and PF3 are identical).

TABLE B-5. Distribution by Rates of Factor-Augmenting Technical Change

	g_{A_R}	g_{A_K}	g_{A_L}
0	17	26	0
.015	19	14	17
.03	15	11	34

TABLE B-6. Distribution by Combinations of Rates of Technical Change

g_{A_R}	g_{A_K}	g_{A_L}	Number
0	0	.03	8
.015	0	.03	8
.03	0	.03	8
All others*			27
			51

* Less than 4 each

One final note of interest is that the simulations did produce
a declining capital-output ratio. Since the "apparent" decline of the
capital-output ratio has been a puzzle to analysts, it is of some
interest to see how this arises in the present model. As is well
known, the capital-output ratio in balanced growth is the ratio of
the saving rate to the rate of growth of the exogenous factor
(usually labor). In a three-factor model, the composite exogenous
factor is the combination of labor and resources, weighted by their
relative shares. But inputs of resources are growing more slowly than labor
inputs, and the share of resources is declining relative to labor's. There-
fore, the growth rate of the composite exogenous factor is speeding
up over time and the equilibrium capital-output ratio is falling.

The Next Fifty Years?

Under the assumption that the models which best correspond to the
stylized facts will apply to the future, we can draw inferences about
the next few decades. All of the best simulations indicate the same
trends; the exact numbers given below are from the best Cobb-Douglas case
(P.F.2), which had $\sigma_{(K,L),R} = 2$, and $(g_{A_R}, g_{A_K}, g_{A_L}) = (.03, 0, .03)$, beginning
at year 150.

Briefly, very little changes. The K/Y ratio declines slightly
(2.53 to 2.52), while shares of capital and labor increase slightly at
the expense of resources (.237 to .240, .711 to .719, .052 to .041 re-
spectively). The marginal product of capital rises (.0936 to .0952).
The growth rate of output rises slightly (.0397 to .0398) while the rate of
change of wages (marginal product per natural worker) approaches 0.03 (up
from 0.0296 to 0.0297).

B.3. Production Models Including Natural Resources: Econometric Estimates.

The simulations described in the last section are quite optimistic about the effects of natural resources on future growth. They imply that growth will accelerate rather than slow down even as natural resources become more scarce in the future. Since the models used there are only suggestive, it is perhaps useful to check the results with a more formal approach.

One of the best simulations was of the following form, PF2: [1]

$$(B.7) \qquad Y = \left[\alpha_1 \left\{ (A_K K)^\epsilon (A_L L)^{1-\epsilon} \right\}^{-\rho} + \alpha_2 (A_R R)^{-\rho} \right]^{-\frac{1}{\rho}}$$

where ϵ was assumed to be $1/4$. In this specification, capital and labor are combined with an elasticity of substitution of one, while the composite capital-labor factor and natural resources are combined with an elasticity of substitution of $1/(1+\rho)$. Let us designate the composite factor as:

$$(B.8) \qquad N = K^\epsilon L^{1-\epsilon} e^{ht}$$

where $\qquad h = g_{A_K} \epsilon + g_{A_L} (1-\epsilon)$

One way to calculate ρ is as follows. The ratio between the shares of the composite factor and natural resources is:

$$(B.9) \qquad z = \frac{\text{share of } N}{\text{share of } R} = \frac{\alpha_1}{\alpha_2} \left(\frac{R}{N} \right)^\rho e^{\lambda \rho t}$$

where $\qquad \lambda = g_{A_R} - h$.

---

[1]. This form won 15 of the top 24 places on Score I.

We use data from Denison for both shares and inputs.[1] These are given in Table B-7 below. The basic estimation is obtained by taking the logarithms of (B.9).

$$(B.10) \quad \ln z = A + \rho \left[\ln(\frac{N}{R}) + \lambda t \right] \quad \ln z = A + \rho \left[\ln \frac{N}{R} + \lambda t \right]$$

where A is a constant. N is calculated from (B.8), taking ε equal to 0.242 from Table B-1 above.

$$(B.11) \quad \ln z = 1.797 - .5046 \ln(\frac{N}{R}) - .0319\, t \qquad R^2 = .9816$$
$$(.026)\ (.3486) \qquad (.0169) \qquad \qquad SEE = .026$$

This regression implies an elasticity of substitution between neo-classicial factors and resources of about 2 and a value of λ of 0.06. It is consistent with the general impression given by the simulation tests -- either the elasticity of substitution is high or technological change is relatively resource-saving or both.

TABLE B-7. Factor Inputs

[1929 = 100]

	Capital	Labor	Resources
1909-1913	57.28	67.58	100.00
1914-1918	65.48	76.10	
1919-1923	77.00	79.32	
1924-1928	90.94	92.12	
1929-1933	101.6	88.74	
1934-1938	99.44	95.76	
1939-1943	106.36	132.06	
1944-1948	114.28	154.14	
1949-1953	136.92	160.68	
1954-1958	162.30	174.40	

Source: Denison, The Sources of Economic Growth in the U. S., op. cit., p. 100, 85.

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[1]. One should give the usual caveats about the data. The labor and capital figures are probably good, but Denison assumes that inputs of natural resources are constant due to the domination of land in natural resource inputs. Since the nonland component in resources has certainly been rising, we understate the growth of R and consequently we probably overstate ε.

APPENDIX C

Population Growth and Sustainable Consumption

1. Equilibrium or Intrinsic Population Growth.

A population is in equilibrium when the number of persons of any given age and sex increases at the same percentage rate year after year. This constant rate is the same for all age-sex classes, and therefore for the aggregate size of the population and for the numbers of births and deaths. In equilibrium the relative age-sex composition of the population remains constant.

Such an equilibrium will generally be reached asymptotically if the fertility and mortality structure of the population remains constant. Mortality structure means the vector of death rates by age and sex. Fertility structure means the vector of male and female births as a proportion of the female population of various ages. The equilibrium rate of growth of a population and its equilibrium age distribution will be different for different fertility and mortality structures.

The net reproduction rate, for a given fertility and mortality structure, is the average number of females who will be born to a new female baby during her lifetime. For zero population growth (ZPG) this rate must be 1.000. When it exceeds 1, the equilibrium rate of population growth per year will depend also on how early or late in life the average female gives birth.

In the text three equilibrium populations are compared, one corresponding to the 1960 fertility and mortality structure, one to the 1967 structure, and one to an assumed ZPG structure. The 1960 and 1967 structures were obtained from the U. S. Census. The ZPG estimates use the 1967 mortality structure, and a fertility vector obtained by proportionately scaling down the 1967 vector enough to obtain a net reproduction rate of 1.000. Figure C-1 shows the three vectors of birth rates by age of woman: 1960, 1967, ZPG.

The differences in equilibrium age distribution associated with differences in fertility structure are illustrated in Figures C-2, C-3, and C-4. These figures also show actual age distributions for 1960 and 1967. The differences between actual and equilibrium age distributions are, of course, responsible for the considerable discrepancies between actual and equilibrium rates of population growth.

Finally, Figures C-5, C-6, and C-7, show for each of the three structures (a) the hypothetical "projection" which the population would follow if the fertility-mortality structure remained constant, given the initial disequilibrium, and (b) the "constant rate" equilibrium path to which the projected path would converge.

These calculations make no allowance for net immigration, which amounts to 300,000 to 400,000 persons per year under current legislation.

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These calculations make no allowance for net immigration, which amounts to 300,000 to 400,000 persons per year under current legislation.

2. Life Cycle Saving and Aggregate Wealth.

As explained in the text, the effect of a change in the equi-
librium rate of population growth on sustainable consumption depends
in part on the change in the stock of wealth the society desires to
hold relative to its income. We have taken the "life cycle" approach
to this problem, as described in Tobin's paper "Life Cycle Saving and
Balanced Growth." [1]

The population is assumed to be in equilibrium, and the calculations
have been made for the three fertility-mortality structures already
described: 1960, 1967, ZPG. It is necessary further to group the
populations in households. This is done arbitrarily by associating
with each female 18 or older:(a) her pro rata share of the living males
two years older, and (b) all the surviving children ever born to an
average female of her age. Males are children until 20, females until
18; at those ages they create new households. Over the life of a
household its average size varies as births and deaths occur.

The household's income each year is the sum of the incomes of
its various members. These vary with age and sex, according to profiles pub-
lished by the Census Bureau and based on the Current Population Survey.
The 1960 profile was used with the 1960 demographic structure, the 1967

1/. In Ten Economic Studies in the Tradition of Irving Fisher,
Wm. Fellner, ed., New York: J. Wiley & Sons, Inc., 1967, pp. 231-256.

profile with the 1967 and ZPG structures. The whole profile is
assumed to shift upward at 3% per year, the assumed rate of in-
crease of productivity due to labor-augmenting technological progress.
Labor inputs of different ages and sexes are assumed to be perfect
substitutes, at rates indicated by the profiles.

Each household is assumed to know its future size n , its labor income
y and the interest rate r . Over its lifetime the average house-
hold consumes all of its income, including interest on any savings
accumulated along the way. The household spreads its consumption
more evenly than its income, saving in high-income years in order
to dissave in low-income years. The utility u of consumption at any
time is taken to be a function of the consumption c per surviving
equivalent adult member of the household at that time. The house-
hold maximizes over its lifetime the sum of the utilities of this
consumption at each age a , weighted by the expected number of equivalent
adult members in the household at that age n(a) discounted by a subjective

rate of time preference: $\int_{a=0}^{A} e^{-\rho a} u\, c(a)\, n(a)\, da$. This is maximized

subject to the budget constraint that expected lifetime income equals
expected lifetime consumption:

$$Y = \int_{a=0}^{A} e^{-ra} y(a)\, da = \int_{a=0}^{A} e^{-ra} c(a) n(a)\, da$$

where $y(a)$ is the expected labor income of a household at age a .
The calculations have been made for the specific utility function
$u(c) = \log c$. This leads to the following rule:

$$c(a) = \frac{e^{(r-\rho)a} Y}{\displaystyle\int_0^A e^{-\rho a} n(a) da} \quad .$$

the limits of integration are the same as before;
where / Y is the present value, at household age 0 , of its expected
lifetime labor income, and the denominator is the discounted sum of
expected equivalent adult years of household life and consumption.
If the market and subjective discount rates were equal, the rule says
that lifetime income should be spread evenly in consumption, so that
consumption per equivalent adult would be constant. To the extent
that r exceeds ρ the household is induced to postpone consumption
until later in life.

As this exposition makes clear, the household's consumption pattern
depends on (a) the way in which its members are counted -- the equiva-
lent adult scale, and (b) the subjective discount rate. Calculations
have been made for various equivalent adult scales, ranging from counting
teenagers and other children as full members to counting them not at all.
In one case the parents are diminishing their old-age consumption in
order to increase household consumption during the years children are

at home; in the other case they are not. Likewise a number of values
of subjective discount rate have been assumed. Some of the combina-
tions are shown in Tables 2 and 4. For the present purpose, which is to
exhibit the effects of changes in the fertility-mortality structure,
the assumed equivalent adult scales and subjective discount rate
matter very little. They would matter if they were thought to vary
systematically with the rate of population growth, but there is no
reason to expect that.

On the other hand, the response of consumption patterns to market
interest rates does matter. It is this response that makes the aggre-
gate wealth-income ratio respond to market interest rates, as illus-
trated in the upward sloping curves of text Figure 1.

Household consumption planning is assumed to be actuarial. A given
cohort of households breaks even over its lifetime. Some households
last longer than average, and some dwindle away sooner. Life insurance
and annuities enable the excess consumption of some members of a cohort
to be met by the excess saving of other members.

Similarly, households are assumed to be able to borrow, as well as
lend, at will at the prevailing interest rate, so long as they have ex-
pected future labor income to borrow against. This assumption of a per-
fect capital market has less effect than might have been supposed,
because in most cases households have few or no years of negative net worth.

Given the consumption plan of an average household, it is
possible to compute at any time the number, the net worth positions,
and the income of households of every age. From this the aggregate
wealth/income ratio can be computed. Along a path of equilibrium
population and economic growth this ratio will be a constant, de-
pendent on the characteristics of the path but unchanging over time.
The reasons that it is a constant of this kind are essentially
(a) that the lifetime propensity to consume equals
unity, regardless of the absolute size of income, and (b) all the
demographic and economic variables that determine the pattern of
household consumption a over its lifetime, and the age distribution
of households and their members, are constant along an equilibrium
path.

As indicated in text Tables 4 and 6, the key economic variable, the
interest rate, is identified with the net marginal productivity of
capital and depends on the capital-output ratio. Here we have also
made the capital-output ratio and the wealth-income ratio identical.
This would not be the case if we allowed for accumulation of wealth
in forms other than capital.[1/] Then the two ratios would differ,

_____

1/. See James Tobin, "Money and Economic Growth," Econometrica, Vol. 33,
No. 4, October 1965, pp. 671-684 and "Notes on Optimal Monetary
Growth," Journal of Political Economy, August 1968, pp. 833-859.

but our conclusions about the effects of population growth would
not be affected so long as the monetary-fiscal policies that de-
termine the difference remained the same.

How does the fertility-mortality structure affect the aggre-
gate wealth-income ratio? The most obvious way is that it determines
the equilibrium age distribution. For example, ZPG puts relatively
more households in the retirement years, when wealth declines to
zero. On the other hand, it also puts more households in the high-
wealth years just before retirement, and fewer in the early low-
wealth years. A less obvious effect is the life cycle of household
size. With ZPG, there are fewer children to claim consumption as
against the retirement consumption of the adults. When children are
counted in the consumption plan, therefore, ZPG raises the peak wealth
accumulations of middle-aged households. The upshot is, as reported
in text Tables 4 and 6, and Figure 1, that reduction in fertility raises
aggregate wealth/income ratios at all interest rates.

FIGURE C-1.

ACTUAL BIRTH RATES, 1960 and 1967, and RATES
ASSUMING ZERO POPULATION GROWTH

FIGURE C-2.

ACTUAL 1960 AGE DISTRIBUTION AND

EQUILIBRIUM DISTRIBUTION
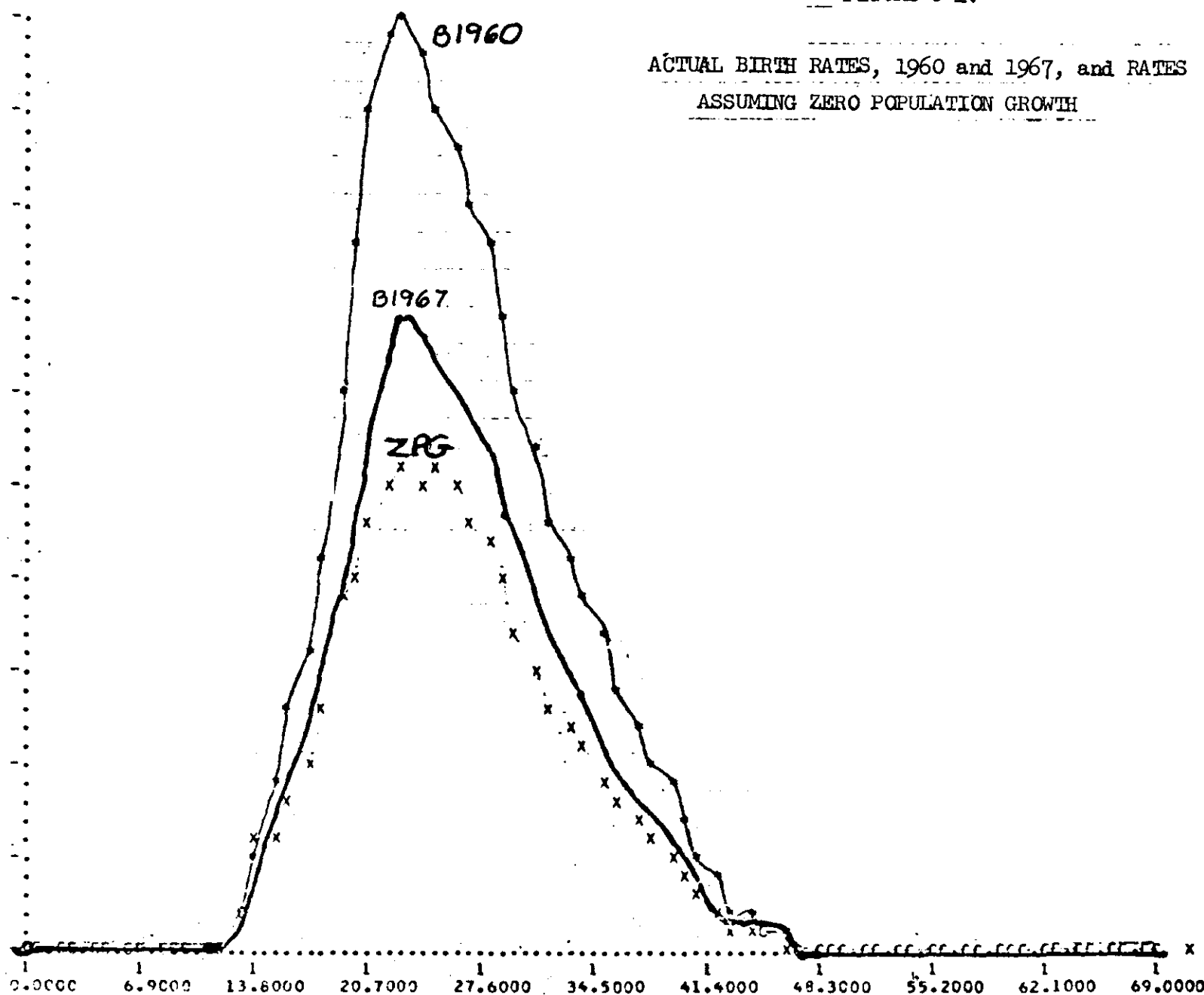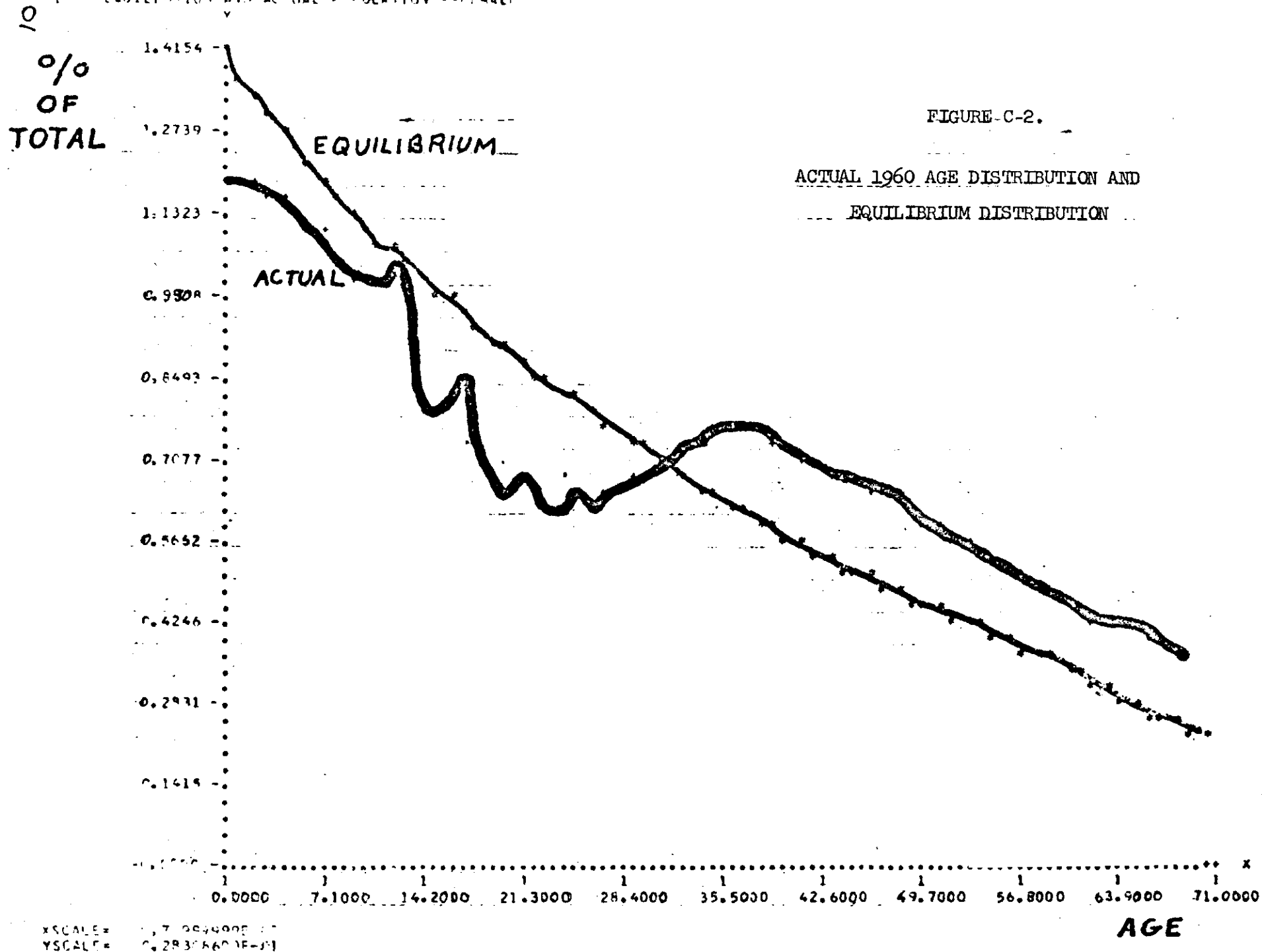
1967 EQUILIBRIUM AND ACTUAL POPULATION --FEMALE

% OF TOTAL

FIGURE C-3.

ACTUAL 1967 AGE DISTRIBUTION

AND EQUILIBRIUM DISTRIBUTION

ACTUAL

EQUILIBRIUM

AGE

XSCALE= 0.70960999E 00
YSCALE= 0.28308600E-01

ZPG EQUILIBRIUM AND ACTUAL POPULATION --FEMALE

FIGURE C-4.

ACTUAL 1967 AGE DISTRIBUTION

AND EQUILIBRIUM DISTRIBUTION

FIGURE C-5.

PROJECTED AND EQUILIBRIUM POPULATION, 1960 FERTILITY-MORTALITY STRUCTURE

1967

POPULATION

572966.2188 -.

534351.2969 -.

455736.3750 -.

457121.4531 -.

418506.5313 -.

379891.6394 -.

341276.6875 -.

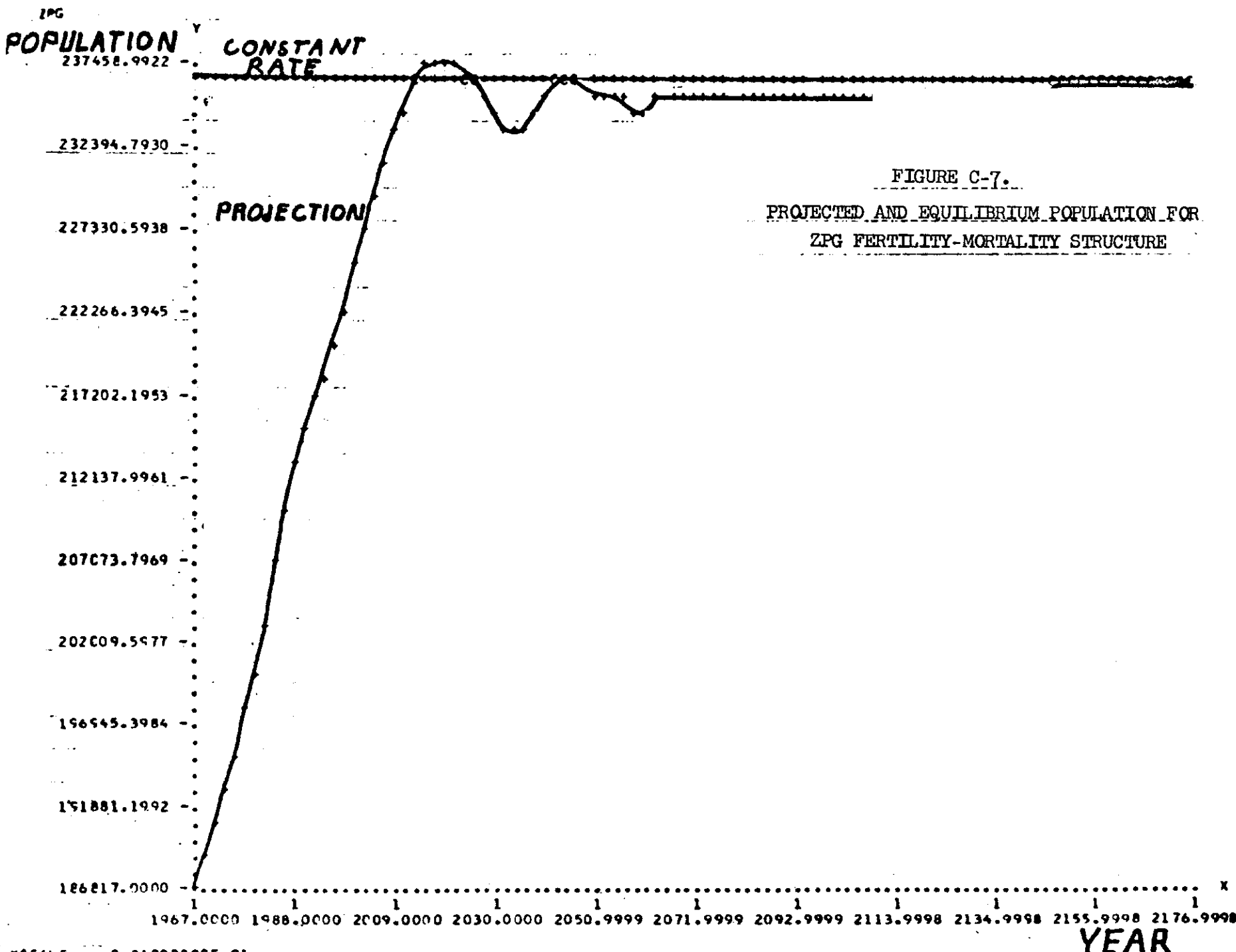302661.7656 -.

264046.8439 -.

225431.9219 -.

186817.0000 -

FIGURE C-6.

PROJECTED AND EQUILIBRIUM POPULATION, 1967 FERTILITY-MORTALITY STRUCTURE

CONSTANT RATE

PROJECTION

X

1 1 1 1 1 1 1 1 1 1 1 1 1

1767.0000 1980.9000 1994.8000 2008.7000 2022.6000 2036.5000 2050.4000 2064.3000 2078.2000 2092.0999 2105.9999

YEAR

XSCALE=   190.0000E 01
YSCALE=   722SA44E 04

ZPG

POPULATION Y **CONSTANT**
237458.9922 — **RATE**

_232394.7930 —

FIGURE C-7.

PROJECTED AND EQUILIBRIUM POPULATION FOR

227330.5938 — **PROJECTION** ZPG FERTILITY-MORTALITY STRUCTURE

_222266.3945 —

217202.1953 —

212137.9961 —

207073.7969 —

202009.5977 —

196945.3984 —

191881.1992 —

186817.0000 — X

1967.0000 1988.0000 2009.0000 2030.0000 2050.9999 2071.9999 2092.9999 2113.9998 2134.9998 2155.9998 2176.9998

YEAR

XSCALE= 0.21000000E 01
YSCALE= 0.0128400E 04