Population Growth Rates and Consumption Demand

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The birth rate in the United States has been declining rapidly in recent years and it is possible that this decline will continue in the future. This change, if it occurs, not only will cause a much smaller rate of growth of population, but will lead to a substantially higher median age. In turn, we may expect substantial changes in the demand for consumer goods and the allocation of that demand among sectors of total consumption.

One goal of this paper is to obtain very long run forecasts of the distributions of consumption expenditures by major sectors. Because the Census Bureau has population estimates through the year 2020, we extend our consumption estimates to that date, although we recognize that the precision of our estimates will decline over time. Forecasts such as these are desirable because they give insight into the changing requirements of consumption of various types of goods. The effort is novel because of the very long period forecast, and the emphasis on the distribution of demand rather than the total level.

A second goal of this paper is the determination of the differing effects on consumption of these alternative demographic changes. The two important elements of this change are the different age distributions of the population under different birth rates and the different levels of income per capita that are likely to be available under these assumptions.

While we know of no paper that has engaged in analysis similar to this one, two main works should be mentioned. Phelps[1] studied the effects of population growth on investment particularly through the use of a growth model. Consumption forecasts have been made by Houthakker and Taylor[2], although these were limited to the year 1975. We engage in a study of consumption with very long run forecasts for a limited number of categories of goods.

Stages of Analysis

The analysis is divided into two stages. The first is specification and estimation of consumption functions for various categories of goods in a fashion susceptible to long run forecasts. The second is the development of the forecasts for each sector of consumption goods. Several alternative sets of estimates are made and compared in order to contrast the effects of the various assumed birth rate patterns we mentioned above.

Specific Model

Our model depends on a demand function which measures quantity consumed as

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[1] Edmund S. Phelps, "Population Increase," *Canadian Journal of Economics*, August 1968, 497–518.

[2] H. S. Houthakker and Lester D. Taylor, *Consumer Demand in the United States*, 2d Ed., Harvard Univ. Press, 1970.

a function of price, disposable income and other demand factors. Consider first the meaning of the price variable. We desire to measure the price of the good under consideration relative to all goods. For sectors such as durable goods the ratio of the sector price index to the all consumption price index is employed. For all consumption together, no such ratio is possible and prices cannot be employed. Because we have relatively few sectors and each is large relative to the whole, we anticipated that the price indexes would be less useful than in an analysis at a very disaggregated level.

The major explanatory variable in our model is total disposable income. Consider the circumstances about a person which make his propensity to consume differ from those of other persons or from his own propensity at a different time. We need to account for such factors in developing individual consumption functions and keep them in the model through our aggregation process. The life-cycle hypothesis of consumption states that a person's consumption-savings decisions will vary over his lifetime. Similarly his choices among consumption goods will be affected over his life and we conclude that his age will affect the specific parameter values of the consumption function.

Next we note that the tastes of the population generally change over time so we also permit the parameters to change as time passes. Both the changes due to a person's age and to the time (calendar year) will be smooth and not subject to erratic variation.

Our model takes into consideration both short run and longer run changes in income and their effects on consumption. To satisfy this we look to the various theories of Duesenberry, Friedman, and Modigliani and their implications. Such alternative variables as past peak income, wealth or lagged income might be employed. Lagged income has the advantage of bringing in no new variable to forecast, so it was selected. While this directly satisfies none of these theories, it does permit the inclusion of cyclical effects and/or permanent income type effects, and achieves high explanatory power.

At this point we employ a consumption function for an individual which specifies that consumption (total or for a major sector) is a function of price and of current and lagged income. The function itself depends on the age of the person, the year and an error term.

We now turn to the specific form to be employed for this model for a single individual. In this discussion we assume the parameters are fixed and consider only Y as the explanatory variable, although our conclusions will be extended to the more general situation. At least four specific functional forms are available and widely employed:

$$C = a_1 + b_1 Y \quad (1)$$

$$C = a_2 + b_2 \log Y \quad (2)$$

$$\log C = a_3 + b_3 Y \quad (3)$$

$$\log C = a_4 + b_4 \log Y \quad (4)$$

In choosing among these or other forms, we look for a model which provides sensible forecasts for long periods into the future. Whereas some equations might be appropriate if the scale of the observations has not changed greatly, we have a situation in which the explanatory variable will more than double in the forecast period. Thus our theory must not only imply that the general form of the model is reasonable but also that the parameters will remain stable over the large scale change.

In (1), b_1 represents the marginal propensity to consume. Over a large scale change consumption will not exceed income, but the ratio C/Y would tend to decline. Although the magnitude may not be great, the effect could be mildly undesirable. The inclusion of time in the equation could correct for this.

Equation (4) is a double log form where b_3 represents the income elasticity of demand for the particular category of consumption goods. Our estimates of this elasticity could reasonably range from close to zero to much greater than unity; a value of three or four would not be unexpected. In forecasting, these coefficients would be very unwelcome, since large values could lead the estimated consumption of a particular category to grow until it exceeded even income. In (2), the marginal propensity to consume is b_2/Y which will decrease greatly over time.

Finally with (3), the marginal propensity to consume grows with time—probably to values considerably in excess of 1 for total consumption. Our discussion leads us to believe that equations (2), (3), and (4) will not forecast well but that (1) has a good chance of being successful. Initial estimation and forecasting with each form confirmed that (1) was the only form to give us reasonable fits and forecasts.

Data

The Department of Commerce publishes annual time series of consumption sectors for 1929 to present. These data include about 100 series including all sectors and subsectors. Quarterly data are available from 1946 to the present for 15 series. The former data, which were extensively analyzed by Houthakker and Taylor, have the advantage of containing the fluctuations in activity of the war and prewar period in addition to the greater number of sectors. The latter have not been so extensively employed and gain from being quarterly observations.

Our analysis is not of a scale to permit the use of 100 series, nor does it seem sensible to forecast very minor categories such as drug preparations of nondurable toys for the very long periods we envisage. Our goal suggests the use of broader groups like furniture or food. Finally we note that the prewar data is a mixed blessing, as the underlying model may well have changed over this period. We chose for this analysis the employment of the quarterly postwar data for 15 categories.[3] Disposable personal income and prices come from Commerce Department data while population and future population are Census Bureau Series.[4]

The price series employed are the implicit deflators for durables, nondurables, services and all consumption. Each of the three sector indices is divided by the all consumption value to get a relative price.

Age and Year Effects

Whereas we concluded that we desire a linear form in specific variables for each individual, we specified that different persons may have different parameters in this linear function. We consider now the effect that these differences will have on the aggregate model. For simplicity of exposition we continue to delete lagged income, prices, and the error term so the equation may read this way:

$$C_i = a_i + b_i Y_i \tag{5}$$

The subscript i refers to the specific person being considered. We indicate that a_i and b_i depend on the calendar year and the consumer's age. We take first the year effect. Since in any aggregate observation it is the

[3] *Survey of Current Business*, July 1971, Table 2.3, p. 23; and *The National Income and Product Accounts of the United States, 1929–1965*, Table 2.3, p. 40.

[4] *Current Population Reports*, P-25, #448.

same for all persons we find:

$$\begin{aligned} C &= \Sigma C_i = \Sigma a_i + \Sigma b_i Y_i \\ &= N a_t + b_t \Sigma Y_i \end{aligned} \tag{6}$$

In this, N is the total number of people while the subscript t refers to the coefficient specific to that year. Since the a and b change between observations, no estimation is possible without additional specification concerning the nature of the change. We indicated above we believed these changes to be smooth and not erratic. If we linearize to correspond to earlier assumptions we have:

$$a_{t+1} = a_t + \alpha$$
$$b_t + 1 = b_t + \beta$$
$$C = N a_0 + N\alpha t + b_0 T + \beta(t \cdot Y)$$

This is divided by N to find per capita consumption and income:

$$(C/N) = a_0 + \alpha t + b_0(Y/N) + \beta(t \cdot Y/N) \tag{7}$$

Per capita consumption is a linear function of time, income, and the cross product of time and income. The last term appropriately belongs in the model if we believe this interaction is important or if we place great importance on our specific linear model. However, since the linearity was a matter of choice and not a requirement of the theory, there is some choice as to whether this term belongs.

We return to the effect of the individual consumer's age (for the moment with no year effects). Now our aggregated consumption function has coefficients which depend on the ages of all consumers. Thus

$$C = \Sigma a_i + \Sigma b_i Y_i \tag{8}$$

In the aggregation process we need to know the number of people of each age, which are the elements of the vector n'

$$n' = [n_1 n_2 n_3 \ldots]$$

n_i is the number of people of age i.

$$\Sigma n_i = N$$

We let A be the vector of coefficients a_i for each age so that

$$\Sigma a_i = n'A$$

This is true because the sum of the a_i is the weighted sum of the different elements of the vector A with the weights being the elements of n'.

It is clear again that we cannot estimate all of the elements of a_i with a single time series without additional information concerning the relation between the a_i. We assume that these values change smoothly as the age increases. As before we linearize both a and b.

$$a_{i+1} = a_i + \gamma$$
$$b_{i+1} = b_i + \delta$$

We adopt the notation:

$$m' = [1\ 2\ 3\ 4 \ldots]$$

It follows that:

$$n'A = a_0 N + \gamma m'n$$

We define

$$\text{Age} = \frac{m'n}{N} \text{ is the mean age of the population.}$$

Then

$$\frac{n'A}{N} = a_0 + \gamma \text{ Age}$$

Similarly

$$b_i Y_i = b_0 Y + \delta_i Z N$$

Z is the weighted average of the age-income cross product with the weights being the number of people with each age.

Our final equation is:

$$\frac{C}{N} = a_0 + \alpha t + \gamma \text{ Age} + b_0\left(\frac{Y}{N}\right) + \beta\left(t \cdot \frac{Y}{N}\right) + \delta Z \qquad (9)$$

As mentioned, the selection of a linear model originally was a matter of choice rather than a hard and fast requirement of theory. Because of the long run forecasts required, it is not likely that the interaction terms in (9) will work successfully. In fact, it is easy to see how they could imply long run propensities to consume greater than one or other similar effects. They were tried in estimation and our a priori beliefs were confirmed. Thus they were deleted while the pure age and year variables were retained.

Although our model requires mean age, our data include median age which we employ as a proxy. We must include lagged income and price in the model, so our final estimating model is:

$$\frac{C}{N} = a_0 + a_1(\text{Age}) + a_2(t) + a_3(p) + a_4\left(\frac{Y}{N}\right)_{t-1} + a_5\left(\frac{Y}{N}\right) + \text{error term} \qquad (10)$$

In this we have renamed the coefficients. The equation is used both for estimates and forecasting.

Estimates

The estimates for this equation were found by employing quarterly data from 1948 first quarter to 1971 fourth quarter, 96 observations. Seasonal dummies were added to the equation but were found to be not significantly different from zero, so they were dropped. Using annual series from the same period, the qualitative nature of the results was very similar to that of the quarterly data; hence the quarterly series with more observations were used. Because serial correlation was present in the residuals, a first order autoregressive transform was undertaken. For three subindustries, the data dictated the use of a second order autoregressive transformation. The estimated autoregressive parameters we employed are shown with our regression results. Because the housing services and household operations categories behaved badly when estimated separately and were similar in nature, we combined them into a single category, housing services and operations, which was found to exhibit more suitable behavior for forecasting. Table 1 presents our regression results.

TABLE I
Regression Coefficients

Sector	a_0 Constant	a_1 Age	a_2 Time	a_3 Price	a_4 Lagged Income	a_5 Income	R D-W	Serial Correlation
Total	946.00	−23.30	2.44		.163	.612	.995	.5
	(2.9)	(−2.3)	(1.1)		(2.8)	(12.5)	2.08	
Durables	1001.50	−19.32	−3.46	−4.25	.157		.874	.7
	(2.1)	(−1.3)	(−1.1)	(−2.2)	(3.2)		1.83	
Autos	142.53			−1.70	.076		.756	.7
	(.9)			(−1.5)	(2.7)		1.97	
Furniture	605.83	−12.82	−2.90	−1.97	.061		.843	.7
	(3.1)	(−2.2)	(−2.2)	(−2.5)	(3.0)		2.25	

TABLE I (continued)
Regression Coefficients

Sector	a_0 Constant	a_1 Age	a_2 Time	a_3 Price	a_4 Lagged Income	a_5 Income	R D-W	Serial Correlation
Other Durables	186.03	−4.02	−.42	−.70	.022		.948	.7
	(3.7)	(−2.7)	(−1.3)	(−3.5)	(4.3)		1.67	
Non Durables	958.13	−16.41	2.88		.179		.961	.7
	(3.4)	(−1.9)	(1.6)		(6.0)		1.74	
Food and Beverages	463.03	−4.50	11.56		.055		.916	.7
	(3.4)	(−1.0)	(1.3)		(3.8)		1.81	
Clothing and Shoes	195.14	−7.35	−3.79		.032	.085	.923	.7
	(1.9)	(−2.3)	(−5.7)		(2.5)	(7.7)	2.54	
Gasoline and Oil	−94.58	5.80	2.23	−.63	.013		.982	.7
	(−2.1)	(5.7)	(8.3)	(−2.8)	(3.8)		1.97	
Other Nondurables	418.40	−6.85		−1.46	.052		.966	.7
	(5.9)	(−3.3)		(−3.5)	(8.7)		2.69	
Services	475.45		12.48	−3.25	.097	.103	.987	.8*
	(5.9)		(10.8)	(−3.9)	(6.2)	(7.1)	2.32	
Housing Services and Operations	−21.97	7.66	7.97	−.55	.022	.032	.990	.8
	(−.2)	(2.6)	(10.3)	(−1.3)	(2.8)	(4.2)	2.03	
Transportation	73.25			−.50	.008	.010	.595	.8*
	(6.2)			(−3.2)	(2.3)	(3.0)	2.19	
Other Services	493.23	−10.01	4.49	−1.81	.060	.056	.974	.8*
	(2.9)	(−1.9)	(3.8)	(5.1)	(−2.9)	(5.2)	1.79	

*A second order autoregressive scheme is used with $\rho = .3$ for the second stage.

Time is measured in years from 1948.
Price is (subsector deflator/consumption deflator) × 100%
Income, lagged income, the constant term, and the sector of consumption are in units of real per capita dollars.

The total consumption equation shows that marginal propensity to consume is 61% from current income and 16% from lagged income or a total of 77%. In addition, per capita annual consumption rises $2.44 each year due to the passage of time and $23. for each year decrease in median population age. A lower birth rate tends to cause an increase in the median age and this in turn will lower total consumption when other factors are not changed. Nondurables show a pattern similar to total consumption. Durable goods' consumption also rises with a decreasing median age but decreases as time passes, other things being unchanged. The price variable shows a $4.25 increase in per capita durable consumption for each one percentage point decrease in the relative price. The services sector as a whole is not significantly affected by a change in median age, but within the sector, housing is positively affected by this variable. See Table I for other specific values.

Data for Forecasts

The estimates above are used to forecast consumption by sector for the future. To make these forecasts we need estimates of future median age, population, income, and prices.

First we look at population forecasts. The U.S. Census Bureau has made estimates of population under various assumptions concerning the birth rate. These estimates are called series B, C, D, and E. B has birth rates which are at levels approximating recent past rates (1960). Series C and D have successively lower rates which are closer to the 1970 rate while E assumes an eventually stable population except for migration. Each series in turn implies a specific age distribution at every future date and a major effect from differing population birth rates will be the marked differences in the median age at the end of the analysis. These differences will have a substantial effect on our estimates of consumption for different sectors.

Next we turn to forecasts of prices in the future. We anticipated that different rates of productivity increase will occur in our three major sectors in the future and hence that their relative prices will change. We assumed that the percentage change for our purposes can be reasonably approximated by the percentage price changes in the past. We found that on the average over the period 1947–71 the relative price of durables decreased by .95% a year, the nondurables decreased by .35% a year, and services increased by .95% a year. These values were used to extrapolate the prices into the future.

Finally, we require estimates of future per capita income. We looked at historical data to see what growth rates have been experienced. For most of the postwar period disposable income per capita has grown at an average rate of around 2.2%; population growth has averaged 1.6%; and total growth of disposable income has been about 3.8%.

One possible assumption is that in the future total disposable income will continue to grow at this same rate. This will be true, however, only if the factors which cause the growth continue in the future as they have in the past. One can view total income as the result of a production function which depends on such factors as capital, labor, and technical change. While the growth of most factors may continue as in the past, growth of the labor force cannot, since we assume the birth rate will decrease in the future. Thus 3.8% is a reasonable upper limit on possible income growth. A lower limit for the income growth might be found by assuming that past growth of per capita income will remain unchanged. This is a rate of 2.2% plus the population growth rate. The latter varies with the population series assumed. For the series considered the population growth rates are: (population series B and 1.5% growth rate); (series C and 1.3% growth); (series D and 1.0% growth); and (series E and 0.8% growth). The correct value would in all probability be somewhere between these lower limits and our 3.8% upper limit. We have chosen to make estimates for five combinations of birth rates and income growth. These have been selected to provide estimates for each of the four birth rate series as well as variation in future income growth. The combinations enable one to compare the same

TABLE II
Consumption Forecasts

		Level	Percentage of Disposable Income
1970	Actual	$2331.	.899
1995			
	B: 3.8	3957.	.852
	E: 3.5	4110.	.838
2020			
	B: 3.8	6577.	.826
	C: 3.8	7371.	.829
	D: 3.5	7266.	.803
	E: 3.5	8039.	.809
	E: 3.0	6371.	.822

TABLE III
Sectors as a Proportion of Total Consumption

Sector	Actual 1970	1995 B 3.8	1995 E 3.5	2020 B 3.8	2020 C 3.8	2020 D 3.5	2020 E 3.5	2020 E 3.0
Durables	.178	.182	.194	.197	.208	.212	.218	.215
Autos	.075	.102	.106	.112	.112	.119	.117	.114
Furniture	.075	.055	.061	.057	.066	.064	.070	.070
Other Durables	.027	.025	.027	.028	.030	.029	.031	.031
Nondurables	.433	.396	.397	.385	.387	.390	.391	.389
Food and Beverages	.216	.177	.167	.151	.146	.137	.136	.141
Clothing and Shoes	.086	.079	.095	.094	.104	.119	.123	.115
Gasoline and Oil	.038	.057	.052	.057	.051	.052	.048	.048
Other Nondurables	.093	.083	.084	.083	.085	.082	.085	.086
Services	.390	.422	.409	.418	.405	.398	.392	.396
Housing	.191	.220	.203	.209	.194	.186	.178	.183
Transportation	.027	.022	.023	.021	.021	.023	.023	.022
Other Services	.174	.180	.183	.188	.190	.189	.191	.191

income growth with two different birth rates for different income growth assumptions. The combinations are: 1. Population series B and income growth 3.8%; 2. Series C and 3.8%; 3. Series D and 3.5%; 4. Series E and 3.5%; 5. Series E and 3.0%. We will particularly emphasize the difference between (1) Series B and 3.8% (high growth) and (4) Series E and 3.5% (low growth). Table II includes present consumption per capita as well as future forecasts both in dollars and as a percentage of disposable income. Table III gives consumption by sector as a proportion of total consumption.

Forecasts

First, one may look at the level of total consumption. For all sets of forecasts, consumption as a percentage of disposable income commences at around 89% for 1970 but drops to 81 to 83% in 2020. Thus we see a substantial increase in personal savings over this period. If this is accurate, the economy will require a change in technology that needs more investment, or outside inducement to invest, or a substantial government deficit to absorb these savings.

Next we look at past levels of per capita consumption compared to the present time. 1970 per capita deflated consumption was about $2331. The growth of this will depend on our population and income assumptions. With high growth of income and population this will become $3957 in 1995 and $6577 in 2020. With very low population growth and 3.5% income growth it will be $4110 in 1995 and $8039 in 2020.

The distribution of consumption by sector is noted in Table III. There is a very substantial increase in durables as a proportion of all consumption goods, centered largely in the automobile sector. Autos gain in part because of the heavy impact of the relative price variable which we forecast will fall in the future. However, in other experimental models without prices, a gain in relative importance was also found. Some authors have suggested that autos will be a declining share of consumption, but our result may foretell the need to go to highly capital intensive consumption goods or may reflect a switch to more expensive and perhaps nonpolluting cars rather than more cars per person.

Nondurables have a very substantial decrease in importance which is centered in the food sector. This decline is associated with the small marginal propensity to consume food relative to its present importance and to a decrease in food consumption with the increase in median population age. Despite their decrease in relative importance per capita, annual food expenditures are expected to grow from their present level of about $500 to $860 if there is high growth, and to $940 with low growth. This growth of per capita consumption is the smallest of any consumption sector but is seen to be quite substantial. Services increase slightly or stay constant depending on the population assumptions employed.

Finally we examine the differences in allocation of consumption among sectors under different assumptions about population growth. The relative importance of income and median age is critical here. Clothing, for example, has a marginal propensity to consume which exceeds its present share of income. Its share of income thus grows faster for lower population growth due to the accompanying higher per capita income growth. In addition, clothing responds favorably to the higher median age implied by a low birth rate, further strengthening this sector's relative position. Furniture behaves similarly and its share of the market also is greater with slow population growth. In contrast, housing, gasoline and food display the opposite behavior. In the other subsectors the effects of varying population growth are minor, and the major sectors reflect the patterns of their above mentioned components. Hence, durables rise to take a greater share with low growth and services with high growth, while the aggregate effects of the nondurable categories cancel one another, leaving their shares unchanged.

This study is dependent on many assumptions and the results are necessarily very tentative. Nevertheless, they may provide an initial look at the changes due for the consumption sector in the future. We can summarize our main conclusions:

1. Total per capita consumption will grow from $2330 to somewhere in the range from $6550 to $8000 by the year 2020.

2. Median age plays a statistically significant role in the explanation of consumption behavior, and in the light of expected substantial changes in this age, should be included in a model of consumption.

3. The savings rate will rise, leading to a need to discover new investment opportunities, or for a substantial government deficit.

4. Changes in consumption will see durable goods increase in relative importance, services rise slightly or remain constant, and nondurables decrease.

5. Relative prices are found to be significant for durables and services categories and are likely to accent the shift in consumptive shares toward durables and away from services.

6. The population growth rate influences consumption in two ways: it changes the median age and per capita income. Given a low population growth rate, there is higher total consumption and a change in the distribution of the sectors toward durables at the expense of services, with little effect on the relative share of nondurables.