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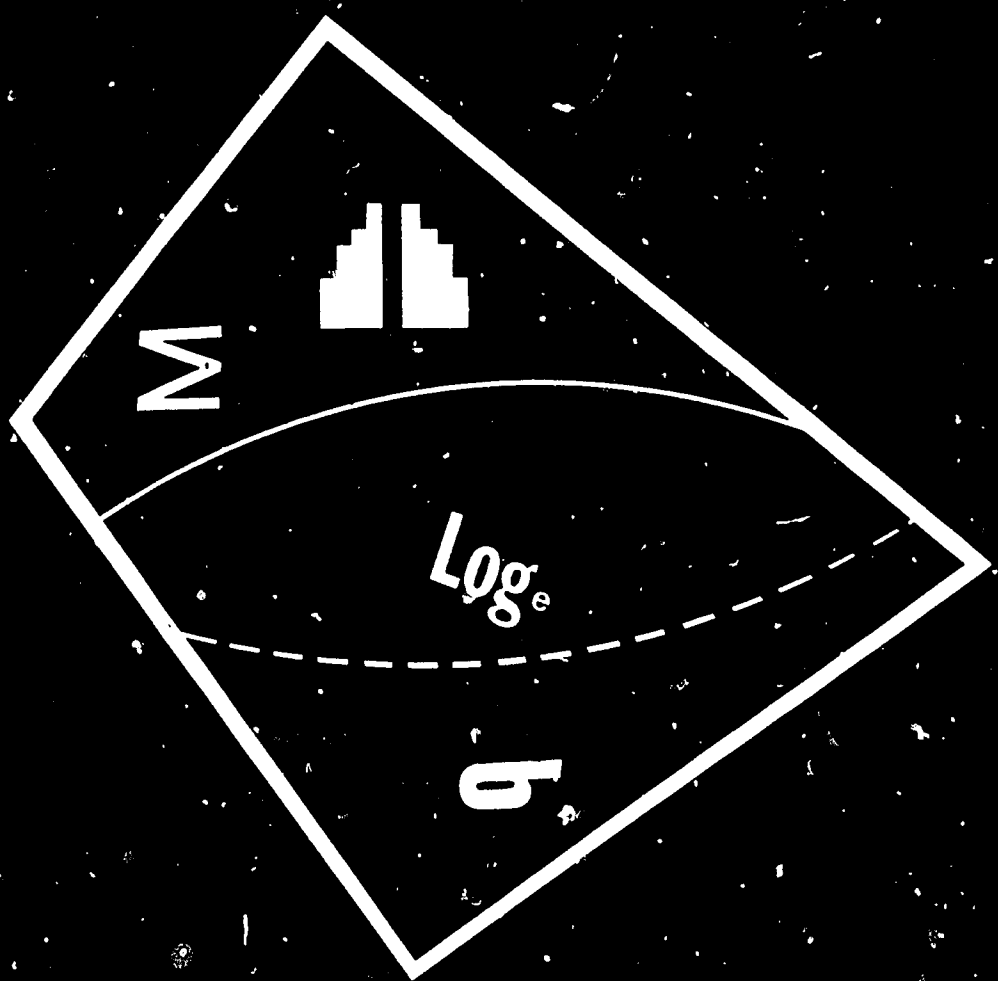
...ulation and Economic Planning

A Macro-Analysis

International Research Document No. 1



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Population and Economic Planning

A Macro-Analysis

by Eduardo Arriaga

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INTRODUCTION

Up to the present, many societies have tried to improve their life standards by increasing their per capita and national products. At the same time they have tried to achieve an equitable distribution of family income. These goals have been achieved by some countries, those known as industrialized. Nevertheless, there are other countries who are far from achieving the economic levels reached by the industrialized states. A large proportion of their population has a low standard of living, and economic prosperity is sought without much success.

In general, the goal of economic development is to increase the national product as fast as possible, in order to increase per capita income in all sectors of society—thereby improving income distribution. Population characteristics have to be considered in the development of plans to reach the economic goal. An economic plan has to consider not only the economic structure of the country but also the social and demographic characteristics of the population. The questions are how much the demographic characteristics affect the economic development, what are the cause-effect relationships, how such relationships can be measured, and—if such measurements are feasible—whether or not the future trend can be predicted.

A final answer to all these questions is almost impossible because of the complexity of the relationships. However, some hypotheses may be formulated from the observation of historical economic trends and population characteristics.

At the time when the industrialization process started—more than a century ago—all countries of the world had a rather low population growth rate. Some of them started the industrialization process while others did not. Does this mean there is no relationship between the demographic variables and economic development?

An affirmative answer would be an over simplication. Although the populations of all countries of the world were growing rather slowly, there were demographic differences, as is shown by their different age structures. Those countries starting the industrialization process had an older population age structure than those which did not industrialize, because the low population growth rate in those countries entering into the industrialization process was a combination of lower levels of fertility and mortality than in those countries which did not develop. In spite of similar natural growth rates, there were definite demographic differences which might have affected the conditions for economic development.[1] There is no question that population age structure and population growth rate—both a consequence of mortality and fertility levels—are related to economic development. This paper will consider only some simple relationships of these two demographic characteristics with some aspects of the economic process.

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[1] Those countries which started the industrialization process did not have population annual growth rates over 1.5 percent. In addition, their age structure registered a proportion of persons under age 15 lower than 38 percent—a proportion which has been continuously reduced since then. On the other hand those countries which did not develop had population growth rates of 1.5 percent per year with an age structure showing more than 40 percent of the population under age 15. Through time, the population growth rates in these countries continuously increased up to levels of 2.5 percent per year—sometimes over 3 percent—and proportions of population under age 15 showed around 45 percent.

POPULATION AGE STRUCTURE

The age structure of a population is closely related not only to the labor force potentiality of the society, but also to the number of dependents as well as the required budget for particular social services directed to those out of the economically active ages. It is not necessary to repeat here how different age structures produce different dependency ratios[2] and how different age structures—even with similar population growth rates—affect private consumer expenditures.[3] Neither will it be repeated how different age structures--with equal or different population growth rates—are related to educational costs.[4] It has already been proved that in relative terms, a population with a young age structure would have to consume lower proportions of the national product than an older population--*ceteris paribus* other variables. In other words, a rather old population age structure would be more favorable for generating savings and hence for economic development than another population with a younger age structure.

POPULATION GROWTH RATE

The rate of population growth affects the growth of per capita income which is related to other economic variables--national product, net investment, output/capital ratio, etc.

The relationship of these variables can be expressed in different forms. Three of them are the following (see detailed deductions in appendix I):

$$\text{(A)} \qquad i = \frac{e^{s} - e^{-r}}{ke^{-r}}$$

$$\text{(B)} \qquad s = \log_e(kie^{-r} + e^{-r})$$

$$\text{(C)} \qquad r = \log_e (ki + 1)\text{-}s$$

Where r is the annual population growth rate, s is the annual growth rate of the per capita product, i is the proportion of national product that has to be invested for obtaining the desirable national product, k is the output/capital ratio, and e is the base of the natural logarithms.

Formula A tells us the proportion of the national product that has to be invested—and hence not consumed—if the population grows at a particular growth rate, if the economy also has a particular average output/capital ratio, and if the planners have as a goal a given growth rate of the per capita product.

The relationship of formula B tells us at what annual growth rate the per capita product can grow in a population with particular values for population growth rate, output/capital ratio, and a capability to save—and hence to invest.

Similarly, formula C tells us at what annual population growth rate a population should grow if the society wants to have a certain annual increase in its per capita product, under certain levels of savings (or investment), with a given output/capital ratio.

The three relationships can be used under hypothetical levels of the variables for the purposes of understanding what might happen in populations with similar economic and demographic characteristics. For instance, table 1 (tabulation of formula A) presents the required investment—as a percentage of the national product—for obtaining a given growth rate in the per capita product (at a rate of 1, 2, 3, or 4 percent per year), under an output/capital ratio (from .25 to .50), and for populations growing at annual growth rates of 1, 2, or 3 percent. As an example, it is possible to say that a population growing at an annual rate of 3 percent per year, with an output/capital ratio of .45 could achieve a goal of a per capita product increase of 3 percent per year, if the net investment is 13.7 percent of the total national product (Table 1, Part C). Under a similar situation of output/capital ratio and desirable increase of per capita product, but in a population which grows at an annual rate of 2 percent, a net investment of only 11.4 percent of the national product would be required for the same goal (Table 1, B).

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[2] Several articles in Joseph Spengler and Otis D. Duncan, editors, *Population Theory and Policy*. The Free Press 1956 and *Demographic Analysis*, The Free Press 1956. Also, Kuznets, Simon, *Modern Economic Growth*, Yale University Press 1966.

[3] Kuznets, Simon. "Population and Economic Growth," *Proceedings of the American Philosophical Society*, Vol. III, No. 3, July 22, 1967, pp. 170-193.

[4] Arriaga, Eduardo, "Impact of Population Changes on Education Cost," *Demography*, Vol. 9, No. 2, May 1972, pp. 275-293.

Table 1. Required Annual Net Investment as a Percentage of National Product, Under a Given Population Growth, Per Capita Product Growth, and Output/Capital Ratio

Output/capital ratio	Annual population growth rates											
	A - 1%				B - 2%				C - 3%			
	Per capita product annual growth rates				Per capita product annual growth rates				Per capita product annual growth rates			
	1%	2%	3%	4%	1%	2%	3%	4%	1%	2%	3%	4%
.25.....	8.1	12.2	16.3	20.5	12.2	16.3	20.5	24.7	16.3	20.5	24.7	29.0
.30.....	6.7	10.2	13.6	17.1	10.2	13.6	17.1	20.6	13.6	17.1	20.6	24.2
.35.....	5.8	8.7	11.7	14.6	8.7	11.7	14.6	17.7	11.7	14.6	17.7	20.7
.40.....	5.1	7.6	10.2	12.8	7.6	10.2	12.8	15.5	10.2	12.8	15.5	18.1
.45.....	4.5	6.8	9.1	11.4	6.8	9.1	11.4	13.7	9.1	11.4	13.7	16.1
.50.....	4.0	6.1	8.2	10.3	6.1	8.2	10.3	12.4	8.2	10.3	12.4	14.5

Other questions can be asked. For instance, a country might have an estimate of the future possibilities regarding the proportion of national product to be invested.[5] In addition, the country could also have knowledge about the output/capital ratio as well as the population growth rate. Therefore, under these circumstances, the question would be, what should be the expected growth of the per capital product? This is presented in table 2, which shows the tabulation of formula B. For instance, if the country can have a net investment of 20 percent of the national product, an output/capital ratio of .40, and an annual population growth rate of 3 percent, such a country could have an increase of the per capita product of 4.7 percent per year (Table 2, Part C). However, if the net investment—which does not include the investment required for replacement—is only 10 percent of the national product, and circumstances relating to population growth and output/capital ratio are the same, then the per capita product would tend to increase at a rate lower than one percent per year—.9 percent (Table 2, Part A).

The situation can be seen from another point of view. Assuming that it is known what proportion of the national product can be saved by the society—hence what might be the net investment—and that the output/capital ratio is also known, what should be the population growth rate in order to achieve a desirable annual growth in the per capita product? This is answered by formula C, which has been tabulated in table 3. For instance, a country that can afford to have a net investment of 15 percent of the national product, with an output capital ratio of .40, and an economic goal of doubling the per capita product in 23 years—which means a per capita product annual growth rate of 3 percent—that country would be able to achieve such an economic goal if the population grows at a rate lower than 2.8 percent per year (Table 3, Part B). If the economic planners are more optimistic and they hope to double the per capita product in 17 years—a growth rate of 4 percent per year—the population should not grow faster than 1.8 percent per year, if the other two economic variables do not change (Table 3, Part B).

The previous examples assume a constancy in the economic variables that never has been recorded. Actually, the output/capital ratio tends to decrease during the process of industrialization.[6] An output/capital ratio of .50 or .45 might be found in a less or underdeveloped economy, but such a level of output/capital ratio would hardly be found in an industrialized country—it would be lower. Investment would also fluctuate during the process of industrialization according to a large number of factors.

If it is accepted that the output/capital ratio declines with the industrialization process, and if a constant growth of the per capital product is desirable, then the proportion of the national product which is net invested should increase and/or the population growth rate should decrease. For instance, let us assume that the net investment in a country will be kept at a level of 15 percent of the national

[5] The estimate can be based on historical information on expected foreign investments.

[6] Kuznets, Simon, Modern Economic Growth, *op. cit.*

Table 2. Annual Percent Growth of the Per Capita Product Under a Given Net Investment, Population Growth, and Output/Capital Ratio

Output/capital ratio	Net investment as a percentage of national product								
	A - 10%			B - 15%			C - 20%		
	Population growth rates			Population growth rates			Population growth rates		
	1%	2%	3%	1%	2%	3%	1%	2%	3%
.25.....	1.5	0.5	-.5	2.7	1.7	0.7	3.9	2.9	1.9
.30.....	2.0	1.0	0.0	3.4	2.4	1.4	4.8	3.8	2.8
.35.....	2.4	1.4	0.4	4.1	3.1	2.1	5.8	4.8	3.8
.40.....	2.9	1.9	0.9	4.8	3.8	2.8	6.7	5.7	4.7
.45.....	3.4	2.4	1.4	5.5	4.5	3.5	7.6	6.6	5.6
.50.....	3.9	2.9	1.9	6.2	5.2	4.2	8.5	7.5	6.5

Table 3. Maximum Annual Population Growth Rates for Obtaining a Certain Per Capita Product Growth, Given a Net Investment and an Output/Capital Ratio

Output/capital ratio	Net investment as a percentage of national product											
	A - 10%				B - 15%				C - 20%			
	Per capita product annual growth rates				Per capita product annual growth rates				Per capita product annual growth rates			
	1%	2%	3%	4%	1%	2%	3%	4%	1%	2%	3%	4%
.25.....	1.5	0.5	-.5	-1.5	2.7	1.7	0.7	-.3	3.9	2.9	1.9	0.9
.30.....	2.0	1.0	0.0	-1.0	3.4	2.4	1.4	0.4	4.8	3.8	2.8	1.8
.35.....	2.4	1.4	0.4	-.6	4.1	3.1	2.1	1.1	5.8	4.8	3.8	2.8
.40.....	2.9	1.9	0.9	-.1	4.8	3.8	2.8	1.8	6.7	5.7	4.7	3.7
.45.....	3.4	2.4	1.4	0.4	5.5	4.5	3.5	2.5	7.6	6.6	5.6	4.6
.50.....	3.9	2.9	1.9	0.9	6.2	5.2	4.2	3.2	8.5	7.5	6.5	5.5

product, that the per capital product growth is planned at 4 percent per year so it will double in 17 years, and that during these 17 years the output/capital ratio is expected to change from .45 to .35. This program will be realistic if it is also expected that the population growth rate will decrease from 2.5 to 1.1 percent per year during the same period of time (Table 3, Part B). Other similar examples can be made by using the formula or the tables. The fact is that in countries where populations will continue growing fast as a consequence of the decline of mortality with a remaining high fertility, any economic plan should also take into account the possibility of a declining output/capital ratio. As a consequence, an increasing proportion of the national product should be invested in order to avoid slowing down the pace of per capital product growth. However, if the population reduces fertility and hence the population growth rate, the possibilities of achieving desirable economic goals increase.

CONCLUSIONS

Demographic characteristics of a population might not be the crucial variables related to economic development. However, they affect and are related to the conditions in which the economic development would occur. Historical experience shows that the countries which have achieved a high level of industrialization were those which had a slow population

growth and a favorable age distribution—not too young—at the time they started the industrialization process. In addition, these countries have had favorable trends of the demographic variables from the starting years of economic development to the present. Both mortality and fertility registered a parallel decline without producing high population growth rates, while the age structures were becoming older.

On the other hand, those countries that did not develop had different demographic behavior. Although more than a century ago they had rather low population growth rates, their age structures were young because of high fertility. Since then, their demographic trends have been toward increasingly higher population growth rates, with age structures changing toward a younger configuration—as a consequence of both declining mortality and continuing high fertility. The effect of these demographic trends in these countries was to create a situation less favorable than if they would have reduced fertility.

Nevertheless, there have been some countries which have started a process of industrialization—rather recently—with a very young age structure and a rapid population growth, for instance, Brazil and Mexico. Does this mean that demographic characteristics are not related to the process of economic development? Actually, this means that there are other variables in the society which probably are also important for economic development. The two mentioned countries have apparently managed to make the necessary investments—domestic or foreign—for starting the industrialization process in spite of the rapid population growth and young age structure. These countries probably also had a high output/capital ratio since they were not highly industrialized in the past.

The question is, how far can a rapid economic development continue in the face of rapid population growth and a possible decreasing output/capital ratio? The possibilities are not too promising unless the population will grow at a slower pace—by reducing fertility and producing an older age structure configuration. Nevertheless, changing demographic characteristics should not be taken as an economic panacea. A slower population growth rate together with an older age structure will not produce economic development. It will only create a favorable situation for economic development. Proper and adequate economic plans together with social collaboration are indispensable for economic success.

APPENDIX

DEVELOPMENT OF THE FORMULAS

If it is assumed that the national product NP at a given year t, (NP_t) grows at an instant annual rate u, and e is the base of the natural logorithms, then

(1) $$NP_{t+1} = NP_t e^u$$

Similarly, if a population P of a country at year t (P_t) is growing at an instant annual rate r, then

(2) $$P_{t+1} = P_t e^r$$

Also, if the per capita national product at year t (PNP_t) is growing at an instant annual growth rate (s), then

(3) $$PNP_{t+1} = PNP_t e^s$$

In addition, the per capita national product is defined as

(4) $$PNP_t = \frac{NP_t}{P_t}$$

Therefore,

(5) $$PNP_{t+1} = \frac{NP_{t+1}}{P_{t+1}} = \frac{NP_t e^u}{P_t e^r} = PNP_t e^{u-r}$$

On the other hand, the increase Δ of the national product (ΔNP_t) during a year is

(6) $$\Delta NP_t = NP_t (e^u - 1)$$

But also the increase of the national product is a function of the increase of the net investment I during the year t (ΔI_t) and the output/capital ratio k—the output of national product per net invested unit of capital. Thus,

(7) $$\Delta NP_t = k \Delta I_t$$

By considering (6) and (7),

(8) $$\frac{\Delta NP_t}{P_t} = e^u - 1 = k \frac{\Delta I_t}{NP_t} = ki$$

Where i is the proportion of the national product used as net investment. Therefore,

(6) $$e^u = 1 + ki$$

but from (3), (5), and (9)

(10) $$e^s = e^{u-r}$$

then

(11) $$e^s = (1 + ki) e^{-r}$$

and hence

(12) $$i = \frac{e^s - e^{-r}}{ke^{-r}}$$

Formula (12) gives the proportion of national product that should be used as net investment given a per capita product growth, a population growth rate and an output/capital ratio.[1] The formula can be transformed for the purpose of obtaining the growth of the per capita product as a function of the net investment, population growth, and the output/capital ratio.

(13) $$s = \log_e (kie^{-r} + e^{-r})$$

Finally, the population growth rate can also be expressed as a function of the other economic variables:

(14) $$r = \log_e (ki + 1) - s$$

---

[1] If in formula (12) the exponentials are replaced by their first approximation—$e^x = 1 - x$—then the formula is reduced to the one presented by H.W. Singer in "The Mechanics of Economic Development" in *The Economics of Underdevelopment* edited by Agarwala and Singh, Oxford University Press, pp. 381-399.

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