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Age Structural Transitions : analysis using the Stationary population equivalent model

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Age-Structural Transitions: Analysis using the Stationary Population Equivalent Model

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Today, we are rapidly moving into a world in which replacement levels or below-replacement fertility is common in many sub-regions of the world. As reported, about half of the world's population now live where total fertility is 2.3 or less (United Nations, 1999). Given the pace of fertility decline in most developing region in the 1970s and 1980s, it is virtually certain that a majority of the world's people will live in places where fertility is below the level of long-run replacement soon. However, when fertility declines to replacement levels or below, population growth continues due to momentum in the age structure (Keyfits, 1971). This momentum will still bring about a high number of births despite low fertility. In our day-to-day observations of population change, we tend to ignore the momentum effects and age-structure. We must broaden our understanding so as to encompass reassessment and explanation for the impacts of age-structure for a wide range of social and economic policy implications. This paper is a first step towards such a reassessment.

I. The Stationary Population Equivalent Model

In this present paper, I propose the use of a measure of population size and growth. The demographic tool I propose is the stationary population that is equivalent, in reproductive potential, to the current population. This measure, which I call the Stationary Population Equivalent (SPE), is the stationary population that would result in an area if it were closed to migration, if mortality remains constant, and if fertility remained at a replacement level.

The calculation of this measure is not difficult at all. It is a weighted sum of the current population where each person's weight is proportional to their future reproduction. For simplicity I will use a model in which only women contribute to future population and in which a woman's future fertility depends only on her age. However, other models, which include the differential fertility for other factors besides age or models allowing for the male contribution, could easily be constructed in a similar manner.

In this model of age-structure assessment, the Stationary Population Equivalent is simply the weighted sum of all women in the current population of reproductive age or younger, where the weight for each woman is determined solely by her age. The weight is a multiple of the number of future female births each woman would have under replacement fertility and the specified mortality. Summing these births gives the size of a generation of females. To obtain the total population this number is multiplied by the number of generations alive at any one time and the ratio of females in a stationary population. The number of generation alive is the ratio of life expectancy divided by the mean age of childbearing. The ratio of males to females in a stationary population is the ratio of life expectancies times the sex ratio at birth. In formal terms, the SPE is computed as:

$$SPE = \frac{\sum_{10}^{50} P_{xf}\, RV_x x e_{of}}{\mu \left[\frac{1 + SRxe_{om}}{e_{of}} \right]} \qquad (1)$$

where P_{xf} is the number of women in the population aged x, μ is the mean age of the fertility schedule, SR is the sex ratio at births and RV_x is the expected future female births of women aged x to x+1 under the give mortality schedule and replacement fertility. Thus RV_0 equals exactly one. RV_x initially increases with age to reflect increased likelihood of survival to the beginning of the reproduction and then decreases rapidly as reproduction occurs. It is close to zero by age 35 and 0 at ages 50 and above. RV_x at age x is calculated by summing female fertility rates at age *y* multiplied by the probability of reaching that age over all remaining ages of reproduction from *x* to 50. The equation is as follows:

$$RV_x = F_x \div 2 + \sum_{y=x}^{50} F_y x L_y \div L_x \qquad (2)$$

Here L_x is the life table population from x to x + 1, and F_x is the probability of a female birth to women aged x to x+1 when fertility is at replacement levels.

The equation (1) can be summarized; SPE can be estimated in accordance with the equation (3) where N relies on female life expectancy, sex ratio at birth and the life span of a generation. As such, N is obtained by the female life expectancy divided by the mean age of the fertility schedule (μ) with adjustment for sex ratio at birth.

$$SPE = \sum P_{xf} * RV_x * \mathrm{N} \quad \text{where} \quad \mathrm{N} = e_{of} / \mu \; [1 + \mathrm{SR} \times e_{om} / e_{of}] \qquad (3)$$

It should be noted that the Stationary Population Equivalent is a special case of the Stable Population Equivalent where the rate of growth, ‘r’, is zero. This Stable Population Equivalent has a long history (see Coale, 1972; Keyfitz, 1971, 1977). The initial births in the Stable Population Equivalent is the constant B_0 in the following equation:

$$B_t = B_0 e^{rt} \qquad (4)$$

Thus the population size involved changes implicitly with time; only if ‘r’ is zero does it refer to a specific population size, that is, a size independent of time. This is an interesting aspect of the SPE model.

The formula for calculating SPE looks fairly complex (see the equation 5). It is a double integral including many terms with e^{rt} terms. The full formula in continuous form is reflected in the following equation:

$$SPE = \left[\frac{\int_0^{50} P_{xf} \int_x^{50} F_y x l_y}{l_{xf} e^{-ry} d_y d_x} \right] x \int_0^{\omega} e^{-rx} l_{xf} d_x \div \int_0^{50} F_x l_x e^{-rx} d_{xf} x \left[1 + SRx \int_0^{\omega} e^{-rx} l_{xm} d_x \div \int_0^{\omega} e^{-rx} l_{xf} d_x \right] \quad (5)$$

where l_{xf} and l_{xm} are the probabilities of survival from birth to age x for females and males respectively, ω is the oldest age for human survival, births are discounted by the growth of the stable population, stable population replace life expectancies, and the mean age of childbearing is for a stable population.

The question remains, however. Other than simplicity, why would you use this model? If all portions of the age structure change size at fairly constant rates, the model does not provide a great deal of information; The reason lies in reality. In many countries, including Vietnam, this is far from the case. In the population of Vietnam, the combination of declines in fertility during the 80s, coupled with changing sex and age structure during and after the war, have lead to markedly different rates of change for various age groups. Thus, the ratio of population at one age to the total population changes significantly. In these circumstances, the rate of growth of the population from the prospective of reproductive potential may be quite different from that the overall population and may be worth studying separately.

II. Calculation and Analysis of SPE for Vietnam

For the present analysis, I have calculated the SPE for Vietnam using the recently released data from he 1999 Population and Housing Census. The information presented in this paper draws on secondary data sources. The census covering all 64 provinces in Vietnam.[1] The absence of national data on population in Vietnam makes the census data valuable.

I used the age specific fertility rates to provide the age pattern of fertility. Fertility declines were recorded in every age group of women (GSO, 2000). The decline was much more prominent in the prime age groups 25-29, 30-34 and 35-39. In addition, the 1999 life table provided the life expectancy at birth as 69 years for females and 67 years for males. The results of calculation are presented in Tables 1. RV_x starts at 1.0 at the time of birth. It increased slowly in the years before reproductive life. RV_x reaches the peak value of 1.09 at age group 10-14, but declines sharply after the ages 20-24, reflecting the number of births born to the woman. The data also show that RV_x is fairly low for the ages of 35 and above. In addition to RV_x, it is necessary to calculate N in equation (3). As earlier indicated, N is depending upon three factors: life expectancy at birth (67 years and 69 years for males and females respectively), the average life span of a generation (29.6 years) and sex ratio at birth (SR = 1.07). The results for Vietnam were shown in Table 1. For Vietnam, N equal to 4.514. Overall, the SPE value for Vietnam is 124,755,982 persons. This number is 61.2% higher than the actual population. In other words, the results represent a momentum of 48.4 million people built in the age-structure of Vietnam in 1999. This increase of the population concentrated in the ages 25 and higher, reflecting the high fertility in the past. The population under ages 25 is however stable (Table 1).

The ratio of the SPE to the actual population has been fairly significant which reveals that the SPE has been growing faster than the actual population (see

[1] As of April 1, 1999 the population of Vietnam was 76,327,173 persons with 16,661,366

Table 2). The ratio serves as to reflect the amount of momentum as measured by the SPE divided by the actual population of Vietnam in 1999. The greatest momentum is found among male population that resulted in the greatest difference between the SPE and actual population (Table 2).

It should be noted in the model that fertility was considered while changes in mortality and international migration were not. In relatively low and stable mortality countries and limited international migration such as Vietnam, there are few predicted deaths and migrants, and there are little room for mortality and international migration to affect the SPE. Their impact can however be studied, using the same model. In particular, each birth above or below replacement will add or subtract the weight of a birth to or from the SPE total. Each death to a woman of reproductive age in excess of the life table prediction, or each emigrant, will subtract the weight of a person of that age from the SPE population, while each death less than the life table prediction or immigrant will add to the SPE according to the weight appropriate for the age of death or international migration. The effects of international migration are less because migrants on the average are older and already have had the opportunity to have children thus the average weight of a migrant is less in this example.

III. Conclusions and Recommendations

Using the SPE model, the growth of Vietnamese population has been declined substantially but the momentum was built up during the high fertility in the past. Because international migration is negligible, the only population growth that occurred in the country was using up age-structure momentum.

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households. Males accounted for 49% and females for 51% of the total population.

The SPE analysis is of a very different picture from that inferred from studying the actual population growth. It may result in a different prospective to population policy. If we are concerned with the long-term implications of population trends, and age-structural transitions, then it would be useful to have measures of population size and growth which are independent of changes on momentum built in age-structure and reflect longer round trends. This is the logic of the SPE analysis.

SPE is very simple to estimate. Calculations can be made for any sub-groups of the population for which the population by age is available. Likewise, it can be estimated separately for rural-urban populations and different countries across geographical regions. The input data is easily obtained in the context of developing countries where data paucity is prevalent. Thus, I recommend its use.

References

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Table 1.- Calculations of the Vietnam SPE, 1999

Age group	*Future female births born to a woman*	*Contribution of each birth on SPE*	*Female population*	*Overall contribution to SPE*
x	RV_x	RV_x*N	P_{xf}	RV_x*N* P_{xf}
0 - 4	1.000	4.514	3484280	15728040
5 - 9	1.058	4.775	4416317	21087914
10 - 14	1.082	4.884	4407685	21527134
15 - 19	1.092	4.930	4094769	20187211
20 - 24	1.077	4.863	3481834	16932159
25 - 29	.922	4.163	3248251	13522469
30 - 34	.634	2.863	3016394	8635936
35 - 39	.368	1.660	2851185	4732967
40 - 44	.177	.789	2364973	1865964
45 - 49	.063	.286	1637191	468237
50 - 54	.013	.058	1171603	67953
55 - 59	.000	.000	1010524	0
60 - 64	.000	.000	990820	0
65 - 69	.000	.000	931102	0
70 - 74	.000	.000	704688	0
75 - 79	.000	.000	520092	0
80 - 84	.000	.000	275210	0
85 +	.000	.000	202454	0
Total			38809372	***124755982***

Table 2.- Results of SPE for male and female populations: Comparing Actual Population and SPE: Vietnam, 1999

Age group	*Male Population*			*Female Population*		
(1)	*Actual Population (2)*	*SPE (3)*	*Ratio (3)/(2)*	*Actual Population (4)*	*SPE (5)*	*Ratio (5)/(4)*
0 - 4	3785092	3141626	0.830	3484280	3152982	0.833
5 - 9	4744753	4108956	0.866	4416317	4056764	0.855
10 - 14	4724101	4610723	0.976	4407685	4582378	0.970
15 - 19	4123771	4585633	1.112	4094769	107218	0.026
20 - 24	3282831	4185610	1.275	3481834	374243	0.114
25 - 29	3225855	4322646	1.340	3248251	532266	0.165
30 - 34	2984912	4790784	1.605	3016394	1208889	0.405
35 - 39	2700475	6238097	2.310	2851185	2565451	0.950
40 - 44	2144357	7271515	3.391	2364973	1833425	0.855
45 - 49	1468162	5627465	3.833	1637191	4536621	3.090
50 - 54	965305	3595761	3.725	1171603	2921978	3.027
55 - 59	793720	2634357	3.319	1010524	2326393	2.931
60 - 64	775759	2940127	3.790	990820	2604999	3.358
65 - 69	750805	3283270	4.373	931102	2785487	3.710
70 - 74	504197	2764008	5.482	704688	2377289	4.715
75 - 79	313633	1723413	5.495	520092	1555933	4.961
80 - 84	143498	969185	6.754	275210	872037	6.077
85 +	87321	666958	7.638	202454	585138	6.701
Total	**37518547**	**61943121**	***1.651***	**38809372**	**59466897**	***1.532***