The demographic determinants of the ageing process and future population size in selected Latin American countries – An application of theoretical issues [#]

Moema G. B. Fígoli [(*)]
Laura L. R. Wong [(*)]

1. Introduction

Substantial discussions about the continue growth of population size and the dramatic fall in fertility in less developed countries are on the way. Discussions range from definition of optimum size (at national, regional or world level) to policy interventions for either modifying the trend of demographic variables implied in the expected population size or how to manage the foretold ageing process.

Most of the current demographic forecasts, however, have significant part of their estimates defined within a narrow interval and so their determinants. This is the case for Latin America, where fertility, mortality, and to a lesser extent, international migration –unless catastrophic events occur– will not differ dramatically from what demographers are expecting. Besides, we know that the main determinant of the future population size (remarkable in the short and medium term) is the current age structure upon which the above variables will operate. Also, we know that in Latin America, due to asynchronic demographic transitions, current age structures are different among the Region's countries.

Thus, future population depends on both the expected trend of the three variables (fertility, mortality and migration) and the current age structure.

This essay therefore considers the effect of these components on the future population size in five Latin American countries that are at different stages of the demographic transition at the beginning of the XXIth century. Several methodological approaches are used for measuring evolution of the age structure.

2. About the selected countries

The countries were selected according to the typical demographic situations that they represent around 2000, as explained next and illustrated in Table 1.

- Rapid fertility decline and currently next to replacement level. There are several larger population size countries experiencing a fertility decline higher than 50% over the period 1965/85, that was, generally speaking, the period of the onset fertility decline in Latin America.

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(*) CEDEPLAR / UFMG / Brazil

Brazil, Mexico and Colombia belong to this category; Brazil is selected because its fertility will be at replacement level very soon.

- Countries that had minimal changes in their fertility levels keeping either high or low levels: Haiti and Guatemala, are examples of the first case; also, they are example of current highest mortality and fertility levels, although the latter has signalled an initial fertility decline. Argentina is a typical example of the second case since its TFR declined less than 10% over the mentioned period. Also Argentina is one of the pioneers Latin American countries entering the demographic transition and – according to most of the forecasts– its fertility will take longer for reaching the replacement level.
- Countries with later onset of fertility decline signalling, however relatively fast decline. It is the case of Peru, whose TFR, around 6,0 even after the seventies, is below 3,5 for the quinquennium 1995/2000.

Table 1
Selected Latin American countries according to some demographic parameters (circa 2000[a])

Country	Population (*)		Annual Growth Rate(***)	Total Fertility Rate (***)	Replacement level to be reached after year:	Life expectancy at birth (***)	
	Total(**)	Under age 30 (%)				Male	Female
Argentina	37.034	53,3	1,26	2,62	2015	69,6	76,7
Brazil	170.113	57,4	1,33	2,27	2005	64,1	71,9
Guatemala	11.384	72,0	2,64	4,93	2035	61,4	67,2
Haiti	8.222	69,4	1,59	4.38	2040	55,8	58,7
Peru	25.659	62,5	1,73	2.98	2020	65,9	70,8

(*) In 2000
(**) Thousands
(***) For the period 1995-2000
[a] Source: United Nations (1999) – Unless otherwise stated, data used in this article are from the United Nations - Population Division.

3. Methods

There is no doubt that Latin–american population will growth for a long while due to the *momentum* effect, defined '*as the ratio of the size of an ultimate stationary population to that of an initial population when the initial population undergoes an immediate shift in fertility to replacement level*'. (Kim and Shoen, 1997, p. 421, based on Keyfitz's concepts)

This paper uses contributions by Keyfitz (1971), Mitra (1976), Kim & Shoen (1997), Bongaarts & Bulatao (1999) and Li & Tuljapurkar (1999), about the underlying process of the demographic transition towards an aged population structure. These ideas are used for analysing the population growth from a given initial period (year 2000 in this case) up to an expected stationarity, considering the role of:

a) The momentum

b) The span that fertility will take for reaching the replacement level.

c) The fall of current mortality till reaching a maximum life expectancy defined is this case, as that used by the United Nations[1]

Keyfitz (1971) estimates momentum assuming an instantaneous drop in the fertility level without changes in the age pattern in an initially stable population. The Keyfitz's momentum expression is:

$$Mk = \frac{b_o \; e_o \; (R_o - 1)}{r \; \mu R_o}$$

Where b_o is the crude birth rate; r is the growth rate; Ro is the Net Reproduction Rate of the initial stable population; e_o is the life expectancy at birth, which is the same before and after transition; μ is the mean age at childbearing of the stationary population.

Mitra (1976) modified Keyfitz's expression to allow for a change in the age pattern of fertility rates. He analysed the effect on momentum of instantaneous drop in fertility for three different models of the net maternity function. The mathematical expression he uses for the momentum is:

$$Mk = b \, e_o \, (1 - r \, \mu^*/2)$$

Where $\mu^* = \mu - \sigma^2$ and σ^2 is the variance of the distribution of the net maternity function.

Preston (1986) argued that the size of the population under generation length, approximately 30 years, remains constant over transition to stationarity and that growth due to momentum occurs entirely above age 30. Kim & Shoen (1997) show that population bellow age 30 does not grow over transition towards stationarity and that the ratio of the initial non–stable population to ultimate population proportions under age 30 is practically identical to momentum. Bongaarts & Bulatao (1999) using Kim and Shoen results define the momentum multiplier for the female population at the end of transition as:

$$M_m = A/A_m$$

[1] The Population division of the United Nations projections implies as a maximum life expectancy to be reached, the values of 82,5 and 87,5 for males and females respectively (United Nations, 2001), which averages 85,0 for both sexes approximately.

Where A represents the proportion of females under age 30 at the beginning of the projection period and A_m is this same proportion at the and of the transition process, i.e., stationarity. They also defined an mortality multiplier, M_d, as a variant of the momentum multiplier equation:

$$M_d = L_r A_m / 30$$

Where L_r is the female life expectancy at the end of the transition in the replacement projection. The fertility multiplier is, according to Bongaarts & Bulatao (1999) (p. 524): '*determined by the extent to which fertility differs from the replacement level over the curse of the projection... ...If the number of years before fertility reaches replacement equals y and the average proportional deviation from replacement during these y years equals d then fertility multiplier can be approximated by:*

$$M_f = (1+ d)^{y/30}$$

Li & Tuljapurkar (1999), differently from Keyfitz and Mitra, study how much will be the momentum for a population whose fertility declines to replacement in a finite time. For countries where replacement fertility was achieved in 15 years or less (*y*< 15) they express the population momentum as:

$$M_1 = M_m ((e^{ry} - 1)/ ry)$$

For slower transitions (*y* between 30 and 100 years) the approximation for the momentum is:

$$M_2 = M_m (1 + ry /2 + r^2 y^2 /6)$$

Where M_m is the Mitra's expression for momentum. The expression M_1 and M_2 assume an initially stable population.

Regarding to ageing process, Kim & Shoen (1997) notice that, '*population momentum and ageing population occur when an initially growing population experiences a reduction in fertility to replacement level. Conceptually and empirically, momentum and ageing express same change, albeit at different scales*'. They show that the relationship between the momentum and ageing (measured by $\Delta A = A_l - A_r$, where A_r is the mean age of the initial stable population and A_l is the ultimate stationary population), is a linear transformation (p. 422):

$$\Omega \approx 1+ \Delta A [(A_l - V_l)/*_l^2]$$

Where V_l is the mean of the tail distribution of the net maternity function (i. e., the mean of the distribution that represents the reproductive value for each age multiplied by the survivorship probability to that age), given by:

$$V_l = \mu/2 (1+ \sigma^2/\mu^2)$$

Where μ and σ^2 are the mean and the variance, respectively, of the net maternity function.

The relationship above shows that that each year of increase in mean population age, from the initial to the ultimate stationary population, is associated with a proportional increase in the initial population size.

In this paper momentum is calculated using the methodologies above and projections estimated for the selected countries[2]. The fertility effect in the population increase is determined using Bongaarts & Bulatao (1999) and Li & Tuljapurkar (1999). The mortality effect is estimated using Bongaarts & Bulatao (1999).

For all countries, three measures of ageing over the transition to stationarity are estimated: the increase in the mean population age, the decrease in the proportion under age 30, and the increase in the proportion over age 65. It is estimated also the proportional increase in the initial population size for each year of increase in population mean age as defined by Kim & Shoen (1997).

4. Results

Table 2 gives results for the momentum applying different methods. It also includes results from two additional projections (I and II) until the ultimate stationary population. Projection I considers fertility at replacement level and life expectancy estimated for the initial population (i.e., in 2000). Projection II considers fertility at replacement level and maximum life expectancy of approximately 85 years for both sexes.

Table 2
Momentum at the end of the transition according different methods and two projections

Country	Bongaarts & Bulatao	Keyfitz	Mitra	Li & Tuljapurkar	Projection I (*)	Projection II (**)
Argentina	1,46	1,27	1,26	1,36	1,33	1,48
Brazil	1,58	1,11	1,11	1,12	1,37	1,60
Guatemala	1,97	1,70	1,54	2,82	1,67	2,01
Haiti	1,94	1,42	1,36	2,06	1,49	1,90
Peru	1,72	1,37	1,29	1,47	1,51	1,73

* Population size at the end of transition (fertility at replacement level and life expectancy in 2000)/Population size in 2000

* * Population size at the end of transition (fertility at replacement level and e_o of about 85 years for both sexes)/Population size in 2000

Source: See the text

- Bongaarts & Bulatao results and Projection II are almost equivalent for the whole set of countries, since assumptions behind them are also similar, i.e., fertility drops immediately to

[2] International migration is not considered in these applications.

replacement level and mortality is established at the lowest limit. Both of them measure the relationship between ultimate stationary population and initial population.

- Values from projection I and Keyfitz and Mitra are similar. Assumptions in these cases are the same: fertility drops immediately to replacement level and mortality remains constant at the observed level in the initial population. Guatemala, Haiti and Argentina present result even more similar due to their relatively stability. Remember that fertility has been almost constant in these countries during the last years and that Keyfitz and Mitra consider the population is stable at the beginning of the projection.
- Results presented for Bongaarts & Bulatao (see Table 3) for measuring both the effect of fertility decline and the span it will take till replacement level in the ultimate population size are coincident with the Lee & Tuljapurkar results about momentum in Guatemala and Haiti. This is due, primarily to the fact that still they are quasi-stable populations and timing for completing fertility transition is expected to be quite long. In the case of Argentina and Peru, where the span of the fertility transition is less than in the previous case, Li & Tuljapurkar's method would give more suitable results than Mitra or Keyfitz methods. In the case of Brazil, the three methods give virtually same results, which is due to the fact that fertility has declined very fast and will get replacement levels in less than 10 years time. Notice for this country that the fertility effect is almost nil.

Table 3 presents the increase of population size till reaching ultimate size, that is, *when fertility moved to replacement level, life expectancy to the presumed maximum and the age structure to its post–transitional equilibrium* (Bongaarts & Bulatao; 1999). It includes absolute values and the effects of the growth population components (fertility, mortality, momentum/age structure)

Table 3
Initial population (2000) and at the end of transition and multipliers factors of fertility, mortality and momentum

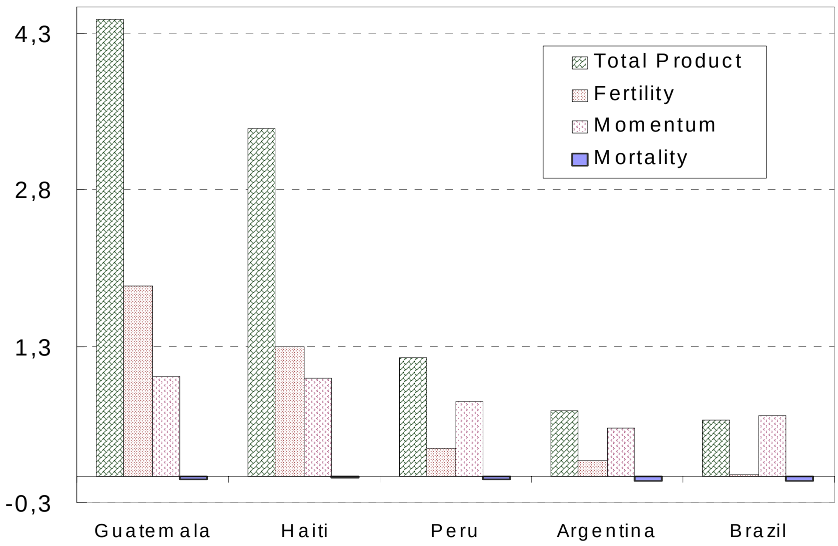
Country	Population size		Bongaarts & Bulatao multipliers			
	2000	Ultimate	Fertility	Mortality	Momentum	Total Product
Argentina	37.034	60.298	1,15	0,97	1,46	1,63
Brazil	170.113	262.552	1,02	0,96	1,58	1,54
Guatemala	11.384	61.172	2,82	0,97	1,97	5,37
Haiti	8.222	35.636	2,25	0,99	1,94	4,33
Peru	25.659	54.987	1,27	0,98	1,72	2,14

Source: See the text.

Figure 1 illustrates importance of these factors; as expected, the largest increments are from countries where fertility is high and age structure is young (Guatemala, Haiti). Countries like

Brazil, that are near to replacement level due to a fast fertility decline will charge almost all future population growth to momentum.

Figure 1. Selected Latin American Contries: Effects of demographic factors in their population size



Effect of mortality which is nearly below 1,0 indicates that the assumption of maximum life expectancy does not compensate the effect caused in the age structure by locating the fertility at replacement level. Furthermore, as argued by Bongaarts & Bulatao (1999), the same rationality used for determining the momentum multiplier can be used for measuring the mortality multiplier when mortality declines over the projection period, thus,

$$M_d = A_m/A_r$$

Where A_r, in this case, is the proportion of females under age 30 at the end of the projection with mortality at the level of 2000 and A_m the proportion determined by the minimum mortality level. As we can see in figure 2, the population proportion under age 30 for the stationary population with e_o for 2000 –used to determined A_r – is greater that the same proportion when mortality level is defined by the maximum e_o –used to determined A_m– for all countries. Thus, for this particular reason –which is, relationships of population under age 30– we can expect a negative effect in the population size due to mortality.

Ageing process of the population is illustrated in Table 4 through three age structure measures for:

- the initial population;
- the stationary population I: implying mortality of the initial population (i.e., e_o at year 2000); and,
- the stationary population II: implying e_o about 85 years.

Table

Measures of the ageing process in the selected countries at the initial moment (in 2000) and at stationarity I and II (*)

Measures	Countries				
	Argentina	Brazil	Guatemala	Haiti	Peru
1. Mean age					
Initial population (2000)	31,80	28,73	22,52	23,65	26,80
Stationary I	38,41	37,20	36,38	34,44	37,86
Stationary II			41,81(**)		
2. Proportion under age 30					
Initial population (2000)	53,31	57,37	71,99	69,45	62,50
Stationary I	40,31	42,13	43,57	46,50	41,20
Stationary II			36,42 (**)		
3. Proportion above age 65					
Initial population (2000)	9,70	5,12	3,53	3,56	4,82
Stationary I	15,91	14,17	13,25	10,60	15,15
Stationary II			21,82(**)		
4. Proportional increase in the initial population size by 1 year increase in the mean age from the initial to the ultimate stationary population					
Stationary I	4,56	4,52	4,23	3,85	4,35
Stationary II	4,84	4,93	4,75	4,61	4,71

(*) Stationary I implies e_o as estimated in 2000
Stationary II implies e_o of about 85 years for both sexes.
(**) Since it has same fertility and mortality functions (i.e. fertility at replacement level and e_o around 85 for both sexes) ultimate population, by definition, is the same regardless of any initial population.

In the first place, stationary population II has an older age structure than stationary population I, which on turn has an older age structure than the initial population. In the stationary population II mean age is nearly 42 years; proportions under age 30 and above 65 are 36,4 and 21,8% respectively. Therefore, the proportion of young people (under age 30) at the initial population is always larger than in both stationary populations and the proportion of old people (above age 65) at the initial population is always smaller that in both stationary populations.

In the second place, related to the stationary population, although ageing process is general; due to different mortality levels, initial differences in the age structure are not the same at the end of the transition. By fixing mortality at the levels found for 2000, Argentina with the highest initial e_o would still have at the end of the process the oldest age structure. Notwithstanding, at the other extreme, populations with the lowest e_o, but not necessarily with the younger age structure (Haiti) would become the youngest country; this is due because in the process to stationarity, populations with high mortality levels, the Net reproduction Rate implies a total fertility rate very often above 2,5 as it was the case for Haiti. Additionally, whether different mortality levels from 2000 remains the same in these countries, ultimate stationary population would imply proportionally, higher increase of those aged 65 and more in Guatemala and Peru, respectively.

Related to the mean age of the population, increase of one year in this measure translates into 3,9 to 4,5% more of the initial population size, when mortality is at 2000 level; as expected when individuals live longer, (e_o around 85 in this case) same increase translates into 4, 6 to 4,9 more of the initial population size.

Figure 2 and 3 at the end of this paper, show the different effects of mortality on the age distribution of the stable equivalent of the initial population and the stationary population I and II. Figure 1 shows that in countries with high mortality and growth rates as Haiti and Guatemala, (see Table 1) the slope of the stable distribution falls faster than others countries as age increases. At stationary population I, in the case of low mortality, as Argentina, population by age is almost constant up to above age 40 and falls fairly rapidly after age 60; in the case of high mortality, as Haiti, population by age decrease fast as age increases. Finally, Figure 3 shows the pyramids formed by the sex and age distribution of the five countries considered.

5. Some concluding remarks

- The concept of population momentum is one of the most important instruments for evaluating future population growth in the short and medium term. Later studies, based on Keyfitz original ideas, incorporating more realistic assumptions have improved usefulness of this concept. Certainly, one important assumption is the timing of setting of fertility decline until reaching population replacement levels.
- The assumption of fertility decline in a rather long period allows evaluation of fertility effects on the future population size, which, on turn, as may be seen on table 2, re–aliments the momentum effect.
- This exercise shows that ageing process in an initial populations that turns out to replacement level depend on the mortality levels and timing of fertility decline. As in the case of Peru and to a lesser extent, of Guatemala, the faster the TFR decline and higher the e_o the more intensive the ageing process.
- Finally, although this is a theoretical exercise, all simulations suggests that population of Latin American countries that started fertility transition several decades ago, will not experience significant growth anymore. Population size of Brazil or Argentina, for instance, even at their ultimate theoretical size (Table 3) will not duplicate. Finally, although the ultimate size would be reached, theoretically in 400/500 years–time, "*almost–stability*" for the five countries studies, that somehow, represent the whole continent will be reached, as everybody expects, at some point between 2050/2100.

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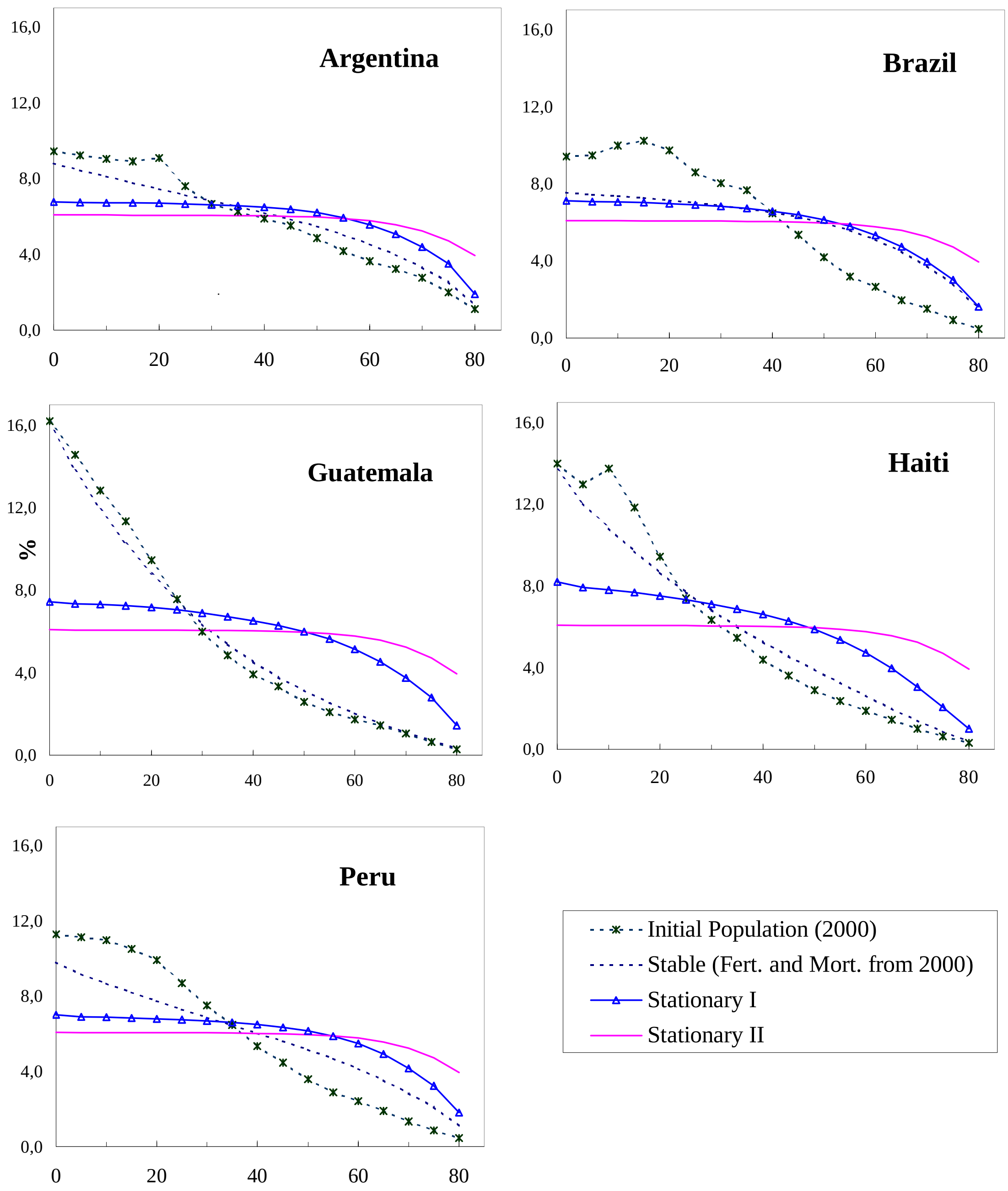
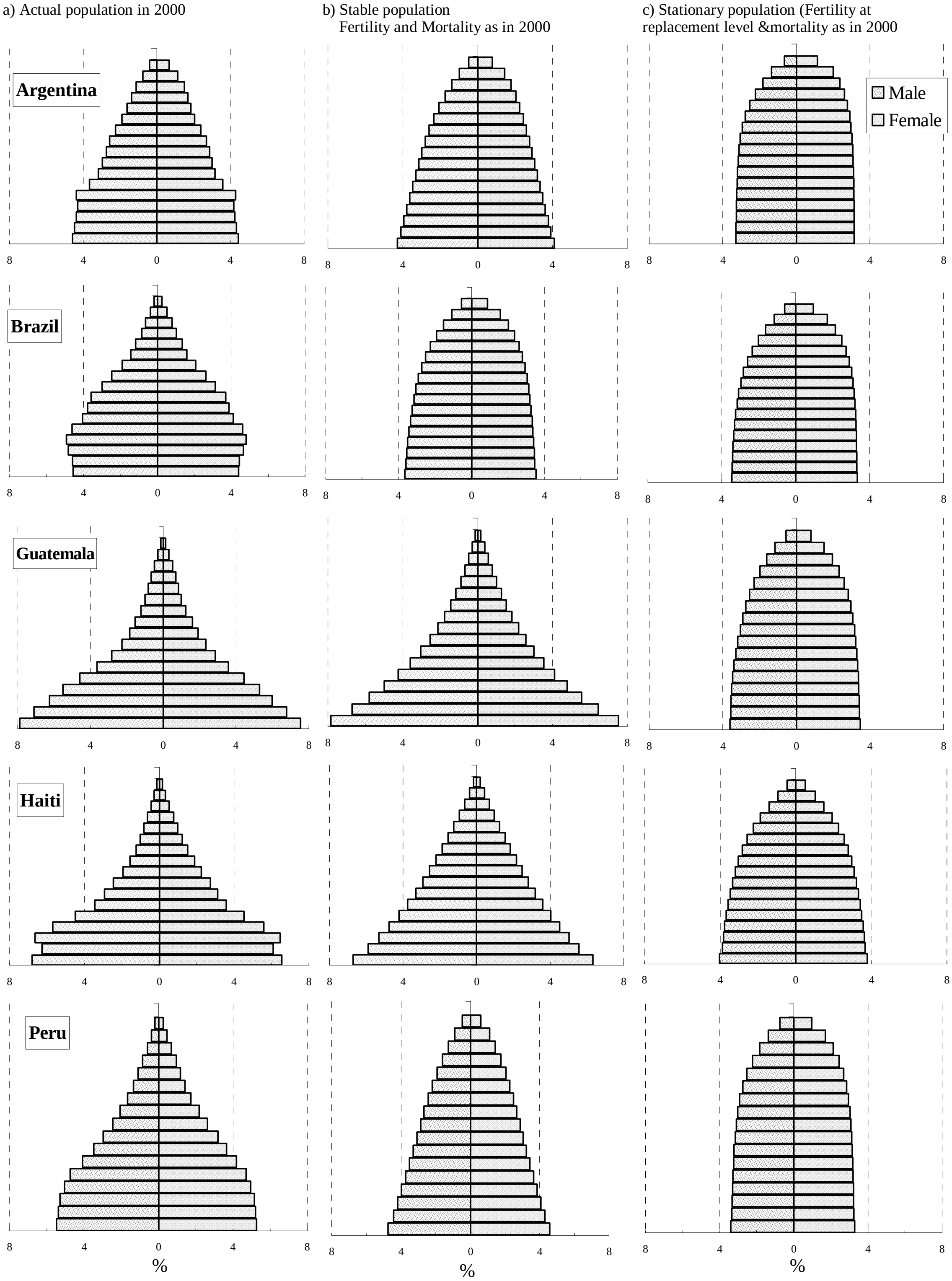
Figure 2: Selected Latin American countries - Relative age distribution of Initial population, Stable equivalent, Stationary I and Stationary II (per cent)



Source: See the text.

Figure 2: Selected Latin American countries - Relative age and sex distribution of Initial population, Stable equivalent and Stationary I (per cent)



Fonte: See the text