"Grow and multiply": social development, birth rates and demographic transition in the Municipality of São Paulo, Brazil, time-series for 1901-94*

"Crescei e multiplicai-vos": desenvolvimento social, coeficientes de natalidade e transição demográfica no Município de São Paulo, Brasil, séries temporais para 1901-94

Abstract

This study reports the construction of time-series related to standardized mortality rate, proportional mortality ratio of Swaroop and Uemura, infant mortality rate, fetal death rate, expectation of life at birth and birth rate for the city of São Paulo, SP, Brazil, from 1901 to 1994. In order to determine the structural variation of these measures, the model, forecast and correlation of these series were submitted to statistical analysis. The results obtained were compared to the historical analysis of the major socioeconomic phenomena during this period in an effort to explain populational movements in the city, with emphasis on the slow and late nature of the process of demographic transition in the city. It was concluded that time-series analysis for demographic measures is efficient in many ways: by allowing the application of statistical methodology to the human sciences, by passing the difficulties inherent in the characteristics of these values (serial correlation, heteroscedasticity, multicollinearity and non-normality of forecast error distribution), by integrating quantitative analysis with the historical interpretation of the phenomena approached, by projecting estimates of future trends on the basis of the behavior of the variables analyzed, and by systematizing the methodology for application in future studies of social research.

Keywords: Mortality rate. Infant mortality. Fetal death. Life expectancy. Birth rate. Time-series. Population dynamics. Municipality of São Paulo. Brazil.

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Resumo

Foram construídas as séries temporais relativas ao coeficiente padronizado de mortalidade, razão de mortalidade proporcional de Swaroop e Uemura, coeficiente de mortalidade infantil, coeficiente de mortalidade fetal, esperança de vida ao nascer e coeficiente de natalidade para a cidade de São Paulo, SP, Brasil, de 1901 a 1994. Com o intuito de determinar sua variação estrutural, procedeu-se as análises estatísticas de modelo, previsão e correlação dessas medidas. Procurou-se associar os resultados obtidos aos principais fenômenos socioeconômicos do período, em um esforço de compreensão dos movimentos populacionais na cidade. Foram sublinhados o caráter tardio e vagaroso do processo de transição demográfica na cidade. Concluiu-se que os procedimentos analíticos de séries temporais são eficientes para o estudo de medidas demográficas, em diferentes sentidos: por permitir a aplicação da metodologia estatística às ciências humanas, superando dificuldades inerentes a esses valores, como a auto-correlação serial, a heteroscedasticidade, a multicolinearidade e a não normalidade da distribuição dos resíduos de regressão; por integrar a análise quantitativa à interpretação histórica dos fenômenos abordados; por projetar estimativas quanto às tendências de comportamento futuro das variáveis analisadas e por sistematizar a metodologia para aplicação em estudos ulteriores de pesquisa social.

Palavras-chave: Coeficientes de mortalidade. Razão de mortalidade proporcional. Mortalidade infantil. Mortalidade fetal. Esperança de vida. Séries de tempo. Transição demográfica. Município de São Paulo. Brasil.

Introduction

The present study is a descriptive effort to characterize the process of demographic transition in São Paulo Municipality through the construction and monitoring of time-series concerning birth rates and expectation of life at birth for the population, as well as other indicators of social development, such as standardized mortality rate, infant mortality rate, fetal death rate and proportional Swaroop and Uemura mortality ratio for the city of São Paulo, SP, Brazil, from 1901 to 1994. The forecast and correlation analysis model was applied to these variables, using habitual statistical procedures for temporal regression and multivariate analysis, as well as the identification, estimate and diagnosis of autoregressive integrated moving average (ARIMA) models.

It is difficult to determine precisely all through these years the quality of the data obtained from both sources researched, i.e., general censuses and birth and death civil registry. Instability and imprecision were attributed mainly to data related to the first half of the century, with probable undernotification of vital events, unintentional faults of measure, operational difficulties or even errors due to regional interests. In spite of this perception, it was decided to aggregate actual data while they are still available since the natural wear and tear of original registers may hinder access to this information in the near future. In this respect, the objective of the present study was to collect and organize the available vital statistics of the city, applying up-to-date computational techniques to statistical analysis, and upgrading the value of data that it was possible to collect each year to delineate hypotheses related to the phenomena approached.

On the basis of the study conducted, an attempt was made to demonstrate the analytical potential of the time-series methodology for social research by integrating the results obtained with the discussion and qualitative interpretation of the major socioeconomic and demographic

phenomena that occurred in the city during the study period. In this respect, the aim was to emphasize the methodology for quantitative analysis and to make it operational in order to demonstrate its potential for application to the human sciences.

Material and Methods

Civil registry data about the number of births (live and still) and deaths were collected and stratified by age range from 1900 to 1994 for the Municipality of São Paulo. Because of the irregular publication of these data in Statistical Yearbooks[1] it was necessary to obtain them from the archives of the "Fundação Sistema Estadual de Análise de Dados e Estatística" (SEADE) (Foundation for the State System of Data Analysis and Statistics) of the State of São Paulo. These data were complemented with a survey of population size in the municipality according to the General Population Censuses[2] of 1890, 1900, 1920, 1940, 1950, 1960, 1970, 1980 and 1991, published by "Fundação Instituto Brasileiro de Geografia e Estatística" (IBGE) (Foundation of the Brazilian Institute of Geography and Statistics), and the State Census of 1934, published in the Statistical Yearbook of 1940.

On the basis of these data, the population of the Municipality was calculated for each year by the arithmetic progression method, with a monthly adjustment, in order to associate the estimates with the middle of the period (July 1st). To make the age structure uniform, the method of Sprague was used based on a computer program[3] developed for this purpose. The division into age ranges used for the calculation of all coefficients was as follows: younger than 1 year, 1 to 4 years, 5 to 9, 10 to 14 and so forth until 75 years or more. The same method was used for the age distribution of yearly deaths.

Crude death rates were calculated, later standardized by the harmonic mean of yearly populational age ranges. Birth rates, infant mortality rates and fetal death rates were also calculated, in addition to the Swaroop and Uemura indicator (proportion of mortality at fifty years or more)[4-6]. A specially designed computer program[7] was used to construct survival tables and to calculate expectation of life at birth for each year. The time-series of these measures were processed statistically using the following softwares: EPI INFO 6.04b and SSS1 from the Center for Disease Control & Prevention (CDC), Atlanta, USA, and from the World Health Organization (WHO), Geneva, Switzerland (1997); SPSS 8.0 (1997) and Microsoft EXCEL 97.

To estimate the parameters of regression with control of first-order autocorrelation (time-series for expectation of life at birth, model A), we used the Generalized Least Squares procedure of Cochrane-Orcutt without Prais-Winsten correction for preservation of the original number of degrees of freedom, according to the methodology described by Johnston[8]. For the configuration of the time-series model with control of higher-order autocorrelation (expectation of life at birth, model B), we used the Generalized Least Squares method as described by Hamilton[9]. The log-linear model described by Gaynor and Kirkpatrick[10] was applied for regression analysis with the introduction of a lagged endogenous variable into the explanatory model of the birth rates time-series. And for the analysis of birth rate forecast, we used the method of Box and Jenkins, autoregressive integrated moving average - ARIMA model (1,2,0) as described by several authors such as Hamilton[9], Gaynor and Kirkpatrick[10] and Harvey[11].

The selection of the models and their fit to each time-series analyzed were based on the need to filter the strong autoregressive movement observed in the original sequences, a peculiarity common to diverse magnitudes of social order. The Kendall-Stuart (Johnston[8]) and Goldfeld-Quandt (Chow[12]; Johnston[8]) tests were also applied for control purposes for the dimensioning of heteroscedasticity in the distribution of regression residues, together with the "z" (Hair et al.[13]) statistic to test the normality

of this distribution, and the Durbin-Watson (Gaynor and Kirkpatrick[10]; Frees[14]) and Durbin-h (Johnston[8]; Gaynor and Kirkpatrick[10]) indicators to evaluate the autocorrelation of these values. For multivariate regression analysis involving the birth rate series, multicollinearity between the explanatory variables was evaluated by calculating the variance inflation factors (Frees[14]), a procedure that resulted in one more element for the validation of the model.

The results obtained with the statistical procedure were integrated into the historical interpretation of populational movements experienced by the Municipality of São Paulo throughout the period studied.

Results and Discussion

1. Measures of social development

Figure 1 shows the standardized mortality rate time-series drawn for São Paulo, from 1901 to 1994. The graphic representation emphasizes important characteristics of the measure such as a global trend to decrease and the non-uniform pattern of its temporal variance (heteroscedasticity).

Very high values were recorded during the first half of the century, with emphasis on the outlier measure of 28.85 deaths per 1,000 inhabitants for the year of 1918, when an epidemics of influenza strongly increased the mortality in the city. Besides the high values observed, the marked amplitude of their yearly oscillation (heteroscedasticity) is another indication of social instability during the period. After the last years of the 40's, this factor was attenuated, and the lesser extent of variability was closely attended by smaller measures for this indicator, registering the former effects of demographic transition in the city. The global trend of this time-series shows a constant and slow decrease of values in the second half of the century, without remarkable signs of cyclic variation.

An analogous feature was perceived for the fetal mortality rate time-series (Figure 2), which was practically stationary up to the mid-forties, a time when it oscillated around the high level of 50 to 60$^{o}/_{oo}$, with a more intense trend to reduction in the subsequent years, indicating the progress of prenatal care, a sensitive reflex of the application of preventive medicine to public health. By comparing the two halves of

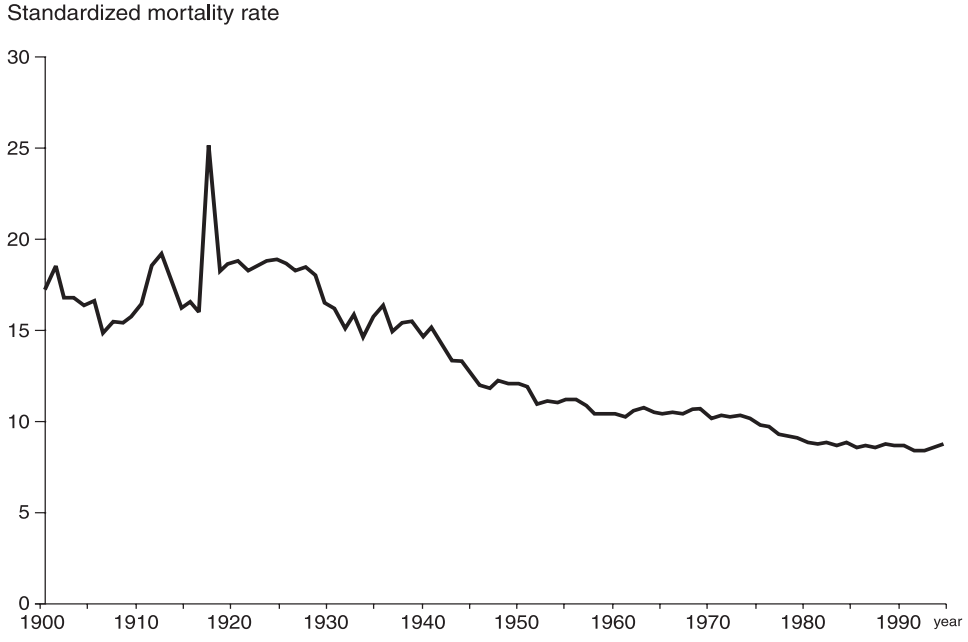

Figure 1 - Time-series for Standardized Mortality Rate in São Paulo Municipality, 1901-94

Figure 2 - Time-Series for fetal death rate in São Paulo Municipality, 1901-94

the century, a pattern of smaller variation in the latter period can be clearly observed (heteroscedasticity), showing the stabilization of the measure around increasingly lesser values. This change in profile may be attributed to the improvement of prenatal care as one more component of demographic transition in the city. It is also worth noting the outlier measure of 29.4 fetal deaths per 1,000 births for 1974, almost 50% higher than the average for the period, the same year in which a severe epidemic of meningitis strained the capacity of public health services, a fact that may have impaired prenatal and delivery care.

As to the Swaroop and Uemura Proportional Mortality Ratio time-series, the increase of yearly measures seems to have been more constant throughout the century, as shown in Figure 3.

The consistent reduction of the infant mortality rate (Figure 4), also in an heteroscedastic way, is another indication of the demographic transition in the city of São Paulo. Till 1948, this rate reached values higher than 100 deaths of children under one year old per 1,000 live borns. However, the decrease of the measure was not constant through the later period. From 1961 to 1973, it increased almost every year, indicating the precarious condition of health care in those years. To explain this local trend of the time-series, Leser[15] suggested an association with the reduction of the minimum wage, while Zuñiga and Monteiro[16] pointed out early weaning of children and the poor quality of the water supply.

The time-series consisting of annual measures of expectation of life at birth for the Municipality of São Paulo also presented a strong pattern of heteroscedasticity, an effect that can be visualized in Figure 5, which illustrates its measures and model trend, and was confirmed by the Kendall-Stuart and Goldfeld-Quandt tests at the $p < 0.01$ level of significance. The initial part of the sequence, characterized by values of smaller dimensions, presented a greater pattern of variance than the last part.

To correct this factor, algebraic modifications of the dependent variables could be attempted, such as those proposed by Box and Cox (Frees[14]). However, the format suggested for the secular trend of the values (and the large number of degrees of freedom authorized) indicated another solution, i.e., the division of the original series into two

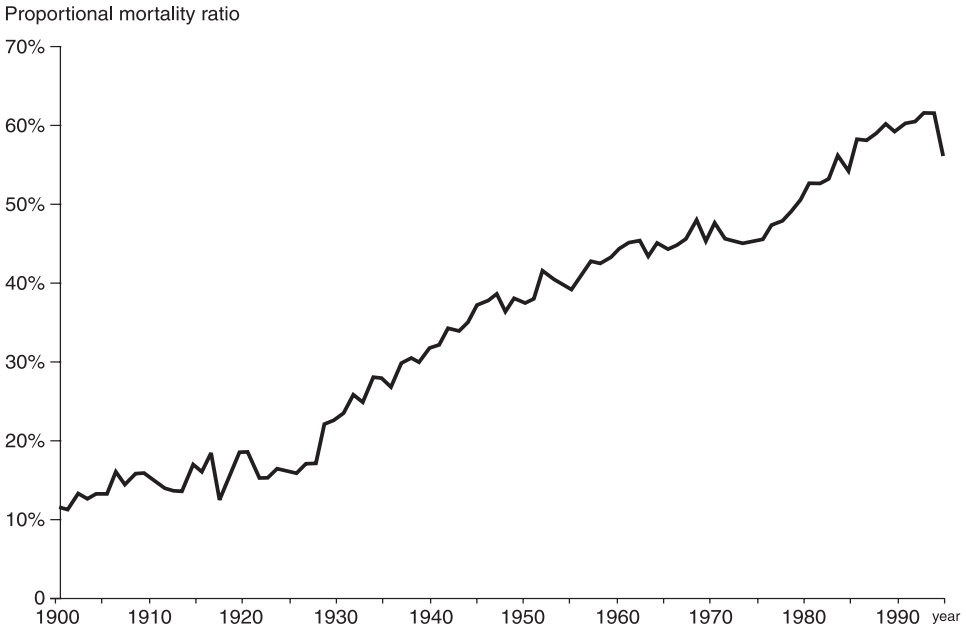

Figure 3 - Time-Series for measures of Swaroop and Uemura proportional mortality ratio in São Paulo Municipality, 1901-94

Figure 4 - Time-Series for measures of infant mortality rate in São Paulo Municipality, 1901-94

models: a parabolic one covering the years from 1901 to 1945, and a linear one covering the years from 1946 to 1994.

The sequence of the two time series, both homoscedastic, permitted a reasonable adjustment between observed and estimated values although they were still subjected to a strong autoregressive movement. In this respect, the parameters for regression analysis were estimated by the procedure of Cochrane-Orcutt, with control of the first-order autocorrelation (AR1) of the first series, and by the generalized least squares method, with control of the first-, second- and third-order autocorrelation (AR-3) of the second series.

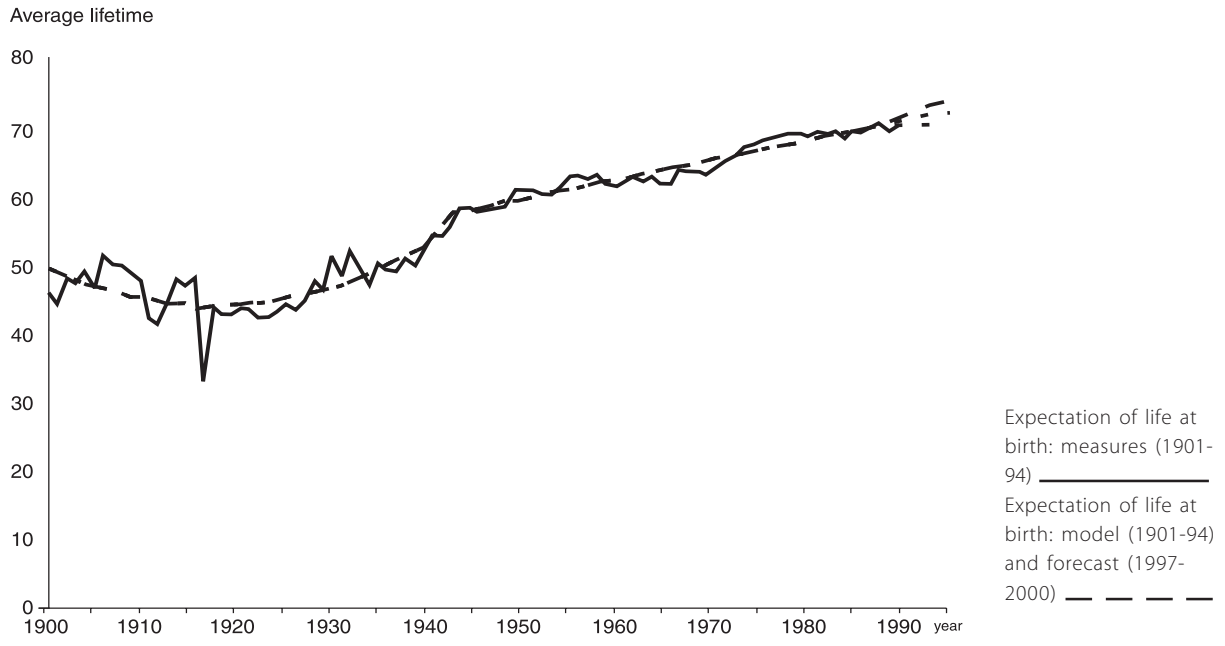

Figure 5 - Time-Series analysis for expectation of life at birth (average time) in São Paulo Municipality, 1901-94

This analysis revealed the significance of the decrease in the values of expectation of life at birth from the beginning of the century to the mid-twenties, when the trend started an inversion movement and a progressive growth that was sustained until the end of the period under study, with a non-modeled cyclic variation of narrow amplitude and wide frequency of oscillation. It was also possible to note the absence of other non-random effects of variation for this measure.

Table 1 lists the results of regression analysis, with quite satisfactory results in terms of the quality of fit. In general, the second segment modeled, with a lower pattern of variance, obtained better indicators; however, its more marked autoregressive movement led to a worse result for the U value of Theil. Nevertheless, the model can be efficiently used for forecast analysis, presenting a narrow confidence interval and a small absolute

Table 1 - Time-series regression analysis for expectation of life at birth (average time) in São Paulo Municipality, 1901-94

GLS Estimates	Model A: AR(1) 1901-1943			Model B: AR(3) 1944-1994		
Regression Analysis	Coefficients	Standard Errors	Significance Levels	Coefficients	Standard Errors	Significance Levels
B_1(year-1900)	-6.525×10^{-1}	1.717×10^{-1}	$p < 0.001$	2.788×10^{-1}	1.745×10^{-2}	$p < 0.001$
B_2(year-1900)^2	1.687×10^{-2}	3.764×10^{-3}	$p < 0.001$	-	-	-
B_0 (intercept)	49.501	1.461	$p < 0.001$	44.238	5.575×10^{-1}	$p < 0.001$
R^2	0.386			0.847		
R^2 adjusted	0.355			0.844		
Standard Error	3.019			0.735		
F	12.582			255.197		
z-test for normality	0.784*		$p > 0.05$	0.290		$p > 0.05$
Durbin-Watson	1.749		$p > 0.05$	1.785		$p > 0.05$
Theil's U	0.685			1.657		

* To achieve this result, the outlier measure for 1918 was excluded.

percentage error for the estimates, as illustrated in Table 2.

It is worth commenting about the outlier measure of only 31.8 years obtained for the expectation of life at birth in 1918, a time when the city, like many others in the country, was experiencing a strong epidemic throughout the period.

The correlation of different explanatory variables was tested in order to delineate an explanatory model for the variations of these measures. We selected the log-linear model with the inclusion of the dependent variable lagged one year, as a strategy to control the

Table 2 - Forecast evaluation for expectation of life at birth (average lifetime) in São Paulo Municipality, 1990-94 and 1997 - 2000

Period		Expectation of Life Forecast	Confidence Interval (95%)	Expectation of Life Measured	Absolute Percentage Error
Ex Post	1990	69.33	67.85 - 70.81	68.77	0.82
	1991	69.61	68.13 - 71.09	69.68	0.10
	1992	69.89	68.41 - 71.37	69.85	0.06
	1993	70.17	68.69 - 71.65	69.02	1.67
	1994	70.45	68.97 - 71.93	70.10	0.50
Ex Ante	1997	71.29	69.81 - 72.77		
	1998	71.56	70.09 - 73.04		
	1999	71.84	70.36 - 73.32		
	2000	72.12	70.64 - 73.60		

of influenza, the so-called Spanish fever, which greatly increased the mortality rate. This factor also affected other measures of social development such as the Swaroop and Uemura indicator, the standardized mortality rate and the infant mortality rate, which also show the expansion of negative indices for that year. The solution adopted for this measure was to incorporate it unchanged for all effects and statistical calculations related to the time-series studied. However, for analysis of the first model of expectation of life at birth, it was necessary to exclude this measure from the calculation related to the z test, since this measure, by itself, increased too much the skewness of overall forecast error distribution, forcing to rule out the initial hypothesis of normality of this distribution.

2. Birth rate

The graphic representation of the time-series related to populational birth rates in the Municipality of São Paulo (Figure 6) shows a more complex pattern of variation than the other series studied. Besides its secular trend of decrease, there is a strong cyclic movement up and down, persistent strong autoregressive impulse of the original series. A close fit between the values estimated with the model and the measures for each year was achieved, as illustrated in Figure 6. With respect to the predictive power of the model, the negative aspect related to the fact that this adjustment always occurred *a posteriori* is emphasized, which impaired forecast of the inflexions of the curve and its changes in behavior either in terms of increasing or decreasing values.

Table 3 presents the values of regression analysis, with excellent indicators of the profile of fit of the model: R^2, adjusted R^2, F, Theil's U, and standard error. This model is suposed to overestimate the goodness of fit measured by the Durbin-Watson statistic. In this respect, the calculated Durbin-h measure supports the hypothesis that the autoregressive movement of the forecast error distribution was effectively controlled. Another indication of the quality of the model resides in the analysis of the variance inflation factors - VIF statistics, performed for the appreciation of the multicolinearity between independent variables, which resulted in acceptable patterns without impairing the reliability of regression analysis.

Figure 6 - Time-series for birth rates in São Paulo Municipality, measures and model, 1901-94, forecast 1997-2000

Table 3 - Time-series regression analysis for birth rates in São Paulo Municipality, 1901-94

Log-linear Model	Coefficients	Standard Errors	Significance Levels
B_1 (birth rate lagged one year)	8.625×10^{-1}	4.129×10^{-2}	$p < 0.001$
B_2 (infant mortality rate)	-6.658×10^{-2}	2.813×10^{-2}	$p < 0.01$
B_3 (wedding rate)	1.443×10^{-1}	3.046×10^{-2}	$p < 0.001$
B_4 (fetal death rate)	3.686×10^{-4}	1.945×10^{-3}	$p > 0.4$
B_5 (Swaroop-Uemura indicator)	-1.057×10^{-1}	2.770×10^{-2}	$p < 0.001$
B_0 (intercept)	8.300×10^{-1}	2.315×10^{-1}	$p < 0.001$
R^2	0.933		
R^2 adjusted	0.929		
Standard Error	4.129×10^{-2}		
F	244.545		
z-test for normality	0.508		$p > 0.05$
Durbin-Watson	2.001		$p > 0.05$
Durbin-h	-5.527×10^{-3}		$p > 0.05$
Theil's U	0.695		

Interesting conclusions may be drawn by observing the rates estimated for the fit between variables. First, the negative sign attributed to the slope relative to infant mortality rate indicates that, the higher this value (a measure that varied substantially during the period under study, ranging from 235.8 to 23.4 deaths per 1,000 liveborns), the lower the collective predisposition to natality measured by the annual birth rate. Second, the also negative sign of the slope for the proportional Swaroop and Uemura mortality ratio is emphasized (another measure that varied substantially during the period under study from 11.8 to 62.6% of the deaths occurring in the 50 years or older age range), indicating that, the lower the proportion of deaths among the youngest, the lower the social need to replace the population through natality and, as a consequence, the lower the value of the measure estimated for the birth rate. Third, the positive sign associated with the slope related to nuptiality indicates the association

between these two variables, supporting the belief that the factors that stimulate or impair the consummation of legal unions also interfere, and in the same direction, with the birth rate recorded in the civil registry. Fourth, the absence of a slope relative to the fetal death rate ($p > 0.4$) suggests that the possibility of a pregnancy resulting in a stillborn fetus (a nightmare for all mothers) varies in a manner independent of birth rates, i.e., it does not interfere significantly with the factors or the calculations that define the beginning of a pregnancy.

The above parameters are better quantified by the estimate of short- and long-run elasticities given in Table 4. Since the explanatory model includes the first lag of the dependent variable, it is easy to understand that effects not only on the birth rates of the current year but also on the birth rates of the subsequent years will correspond to the oscillations recorded for the independent variables. In this respect, one may state, for example, that for each 1% increase in the wedding rate, with the remaining conditions of the model being unchanged, there will be a corresponding 0.14% increase in birth rates for the same year, another 0.12% increase in birth rates for the following year and so forth, with successively smaller increases each year for a total 0.85% increase in the total number of births. The same reasoning applies to the Swaroop and Uemura indicator and the infant mortality rate, keeping in mind the inversion of proportionality dictated by the negative sign of the elasticities calculated.

Table 5 summarizes the forecast analysis for birth rates in the Municipality of São Paulo according to the autoregressive integrated moving average (ARIMA) model (1,2,0) selected and estimated according to the methodology of Box and Jenkins. It can be seen that the absolute percentage errors calculated for the *ex post* period are reasonably small, representing a factor indicative of the quality of the forecasts made. The model also indicates the possibility of a reversal of the tendency to a fall in the annual birth rate for the *ex ante*

Table 4 - Calculated elasticities for the log-linear regression analysis of birth rates in São Paulo Municipality 1901-94

Independent Variables	Short-run Elasticity current year		Long-run Elasticity next year
Infant mortality rate	-6.658×10^{-2}	-5.742×10^{-2}	-3.917×10^{-1}
Wedding rate	1.443×10^{-1}	1.245×10^{-1}	8.489×10^{-1}
Swaroop-Uemura indicator	-1.057×10^{-1}	-9.116×10^{-2}	-6.217×10^{-1}

Table 5 - Forecast evaluation for birth rates in São Paulo Municipality, 1990-94 and 1997-2000

Period		Birth Rate Forecast	Confidence (95%)	Birth Rate Measured	Absolute Percentage Error
Ex Post	1990	21.653	18.835-24.471	20.707	4.57
	1991	19.220	16.403-22.038	20.153	4.63
	1992	19.106	16.288-21.923	19.815	3.58
	1993	19.377	16.559-22.195	21.033	7.87
	1994	21.449	18.632-24.267	21.213	1.11
Ex Ante	1997	23.003	20.185-25.821		
	1998	23.524	20.706-26.342		
	1999	24.069	21.251-26.887		
	2000	24.620	21.802-27.438		

period. This indication should be viewed with caution because of the relatively wide amplitude of the confidence intervals delineated by the model, a fact that also involves the hypothesis that this measure will remain stable during the forecast period.

Historical Interpretation

The Second Founding of São Paulo at the end of the 19th Century

The 1872 census recorded 23,243 inhabitants for the Municipality of São Paulo, a value that indicated a perceptible population growth compared to the 1836 and 1855 measures, respectively corresponding to 12,256 and 15,471 inhabitants. Historians[17,18] and chroniclers of the time pointed out that, from the viewpoint of the agricultural exporting economic model, São Paulo was the Capital of a prosperous and important Province although it had not been able to free itself from the patterns of urban life dictated by the colonial period. The explosion of the coffee growing production had not yet affected the city, with only sporadic loads transported by animals crossing the city in the direction of Santos, most of them coming from Campinas or more northern locations. Before railroads were built, the entire region of the Paraíba valley - the first to benefit from intensive coffee culture - was an economic tributary of Rio de Janeiro, since its production was exported through its port, a fact that increased the profit of the Court at the expense of the Province.

This situation only started to change after this period, when various innovations modified the quiet and sleepy atmosphere of the city. The streets of the central perimeter were paved with stone, new public streets were opened and others were extended and widened. Kerosene street lamps were replaced with gaslight, the telegraph and piped water networks were expanded, and the first street-cars drawn by donkeys were inaugurated. In addition, several public facilities, such as lazarettos (public hospitals for quarantine), schools and an insane asylum for the "alienated" were built.

Where did the wealth that subsidized this outburst of progress in São Paulo come from? The answer is quite clear. Coffee, railroads and immigration were the three factors that converged to project São Paulo as one of the most outstanding centers on the Brazilian scene. Attempts had long been made to extend coffee growing throughout the São Paulo territory, but the cost of transportation from more remote regions consumed the profits obtained from coffee sales, no matter how large the production. However, after 1870 it was possible to expand coffee plantation to the northern and western portions of the Province, where geoclimatic conditions were quite favorable for the increase in production. This expansion would not have occurred without the construction of several railroads that permitted the transportation of crops from more distant areas. Also, the coffee-growing activity would not have projected to such an extent without the large-scale introduction of manpower represented by European immigrants, who compensated for the scarcity of slaves and for their proclaimed inability to apply more recent agricultural techniques.

The railroads not only made it easier to sell coffee, but also contributed to the settling of the hinterland. The railroads gave free tickets to the immigrants who were going to settle on farms and also interconnected a vast region through river transportation, stimulating steam navigation. They also stimulated the cattle industry by supplying refrigerated cars for meat export and contributed to the establishment of the first meat packing houses in the country. In fact, the railroad companies subsidized the beginning of industrialization in the state of São Paulo by offering loans at low interest, and by facilitating the transportation of products and of raw materials. In addition, the expansion of coffee culture had another invigorating effect on the Capital and on towns in the hinterland: the sim-

plification of farming and the practice of monoculture forced coffee growers to look for food in urban centers, since foodstuffs were no longer produced on the farms.

However, the railroad network was not the only factor responsible for the economic development of the Province and for the growth of the Capital. It is well known that this development would not have occurred without the massive introduction of foreigners not only to provide the manpower necessary for coffee planting, harvesting and processing, but also to expand industry and trade. The traffic of African slaves had been definitely abolished in 1850 and most of the slaves remaining in other Provinces were soon sent to São Paulo. Previous attempts to stimulate immigration had been unsuccessful and the local population was small and resistant to proposals of moving to the country. In fact there was no way of increasing the work force in São Paulo unless the Provincial and Imperial Governments applied vigorous measures to attract Europeans to coffee-growing activities.

Provincial Law number 42, of March 30, 1871[18], authorized the emission of Government bonds to cover the cost of boat fare for the immigrants. In August of the same year, the Association for the Aid of Colonization was created to provide resources for settlers that would look for employment on farms and for their families. Ten years later, with the success of this initiative, immigration became more intense, thus providing the manpower required by the prosperous urban commerce and by the progressive industrialization of the Capital. To further stimulate this process, Provincial Law number 36, of February 1881[18], increased the allotment to each settler in order to reimburse traveling expenses, and created the Immigrant Hostel in the Capital in order to shelter newly arrived immigrants until the time their functional situation would be defined.

Despite the opposition of some of the more conservative farm owners, immigration continued to grow during the last years of the Empire, demonstrating the countless advantages of free labor compared to slave labor. Free workers were better fed and showed greater productivity. They did not need to be restrained with threats and physical punishment, they did not resist the adoption of agricultural machinery, and they were also preferred for urban work.

An evaluation of the results of the immigration policy during the Imperial period shows that, according to the censuses of 1872 and 1886, the proportion of Europeans in the population of the Province grew from 1.2 to 4.4%, an index that would reach even higher values during the first years of the Republic. To measure the effects of immigration on the industrial and commercial expansion of the Capital during the same period, the same index indicated an even more intense growth, from 8 to 25%. Since they owned no land, the European immigrants were highly mobile and many of them became aware of the disparity between urban and rural opportunities. Thus, many of them started to settle in the Capital, which was beginning to show its progress towards a metropolis[17]: 23,243 inhabitants in 1872, 44,030 in 1886, 64,934 in 1890, and 192,409 in 1893!

Coffee, railroads and immigration: these were the three factors responsible for the progress of São Paulo, for the increased Brazilian exports and for a more dynamic economy for the country as a whole. They were also causes of renewed vigor in the Capital, which became the second most important center on the national scene within a short period of time. The 1870 decade marked the beginning of an intensive growth and modernization process for the city of São Paulo, a period of genesis of the future metropolis during which agricultural profits were applied to improve living conditions in the cities. This process advanced even more during the years that followed the proclamation of the Republic, leading to such important changes in the Capital, that some historians[19] suggested that the end of the 19th century should be defined as the "second founding" of the city.

Industrialization and Urbanism: 1900-1930

An understanding of the urban renewal process experienced by the city of São Paulo after the end of the 19th century is fundamental for the subject under study, since the population movements that occurred during the period from 1900 to 1930 were subjected to the continuity and intensification of this process.

In those years, the migratory process, which had been increased after 1908 by the arrival of Asians, brought approximately one million people to the port of Santos. A little more than half of them returned to their place of origin after some time, with emigrants from Portugal, Japan and Eastern Europe tending to remain in Brazil. Furthermore, the flow in and out of the town was intensified by the lower stability of urban migrants compared to rural migrants and by the attraction felt by the rural population for the increasing opportunities available in the city.

The dynamic manner in which the migratory movement was forming the population of São Paulo helps to explain the consistent trend of a fall in expectation of life at birth observed for the Capital during this period. The constant inflow and outflow of migrants affected the calculation of this indicator from several viewpoints.

First of all, most of the foreigners who were trying to settle in the city suffered several deficiencies. If a better situation had been available to them in their places of origin, perhaps many of them would not have opted for emigrate. In addition, upon their arrival in Brazil, the immigrants found living and working conditions that had nothing to do with the propaganda that had stimulated them to come. Indeed these conditions differed little from those to which the slaves had been submitted until a short time before. Moreover, the various epidemics that rampaged through Brazil at the time, more than increasing their disappointment, spread panic among the Europeans who were known to be more susceptible to tropical diseases for immunological reasons. Diseases such as yellow fever and typhoid fever were ironically defined as "patriotic" because they seemed to prefer foreigners to Brazilians. In this respect, an anecdote of the time, making fun of the Portuguese, stated their lower resistance to yellow fever and claimed that they intended to avoid contagion by collectively applying for Brazilian citizenship.

Second, it seems justified to think that the many foreigners who did not remain in Brazil, having returned to their countries of origin at their own expense, had more means than those who were arriving, most of whom needed support for the trip. Thus, we may say that the population of the city formed by the migratory process was peculiarly heterogeneous, with more affluent contingents being replaced by less privileged ones. And this process definitely had some weight on the production of the annual indicators of social development, as registered by the decrease of the expectation of life at birth for those years.

Throughout the period known as "Old Republic" (1889-1930), immigration not only satisfied the need for expansion of the work force for agricultural activities, but also contributed to the industrialization of São Paulo. This manpower satisfied the requirements for quality more than for quantity, since local schools were not yet training technicians, mechanics or metal workers. Other factors in addition to migration contributed to the growing industrialization of the urban nucleus: the capital accumulated by coffee growers; the transport facilities provided by the railroad network; an accessible and populous market with a higher acquisitive power than the average for the country; the availability of raw materials for basic industries such as fabrics, ceramics, foodstuffs and furniture; access to abundant and low-cost energy resources first provided by steam and hydroelectric plants and later also by oil derivatives. These factors, taken together with the international economic depression that accompanied World War I, help explain

the process of industrialization that occurred in the city of São Paulo earlier than in other South American cities. The interest of the former republican government in preventing the wealth obtained by agricultural production from returning abroad for the acquisition of manufactured products should also be emphasized. Indeed, protectionist tariffs against importation were part of this trend.

From Immigration to Internal Migration: 1930-1970

Since its early years, the republican period was marked by increased State intervention in the field of public health. However, one cannot state that social policies were applied at that time since social well-being as a target for govern-mental action had not yet been formulated. The authorities of the time were not motivated by beneficent impulses, but were more interested in adopting sanitary measures for economic reasons. It is clear that at the state level the many governmental initiatives in this area aimed at producing more stable urban and rural living conditions in the State of São Paulo. However, this was not a goal to be reached, but rather the strategy selected to favor an increasing expansion of agricultural, industrial and commercial activities in the State.

On the one hand, the governments of various European countries threatened to interrupt emigration unless more effective measures were adopted to control the tropical diseases that decimated the population. On the other hand, sanitary difficulties created dissatisfaction among the population, and the diffusion of contestatory ideas during a period marked by anarchist preaching was feared by the government. The precarious hygiene conditions jeopardized the desired expansion of the work force in towns and in the country, a prerequisite for economic expansion and for the replacement of the recently abolished slave manpower. The industrialization occurring in the Capital, trade in general, and the increased export of coffee required improved sanitation in order to attract an even larger number of immigrants and induce them to settle in their new occupations.

Even though the movement for the expansion of state intervention in the sanitary field decreased after the first positive signs were obtained in terms of the control of great epidemics (yellow fever, bubonic plague and smallpox), the resources applied permitted sanitation work and the creation of public hospitals and of institutions dedicated to experi-mental medicine, to vaccination and to the production of medication and therapeutic sera. A greater private investment in this area supplemented these activities. By mid-century, a wide hospital network had been established in the city of São Paulo starting from the initiative of immigrant communities which, following the example of mercy brotherhoods, had organized in order to assist their compatriots. Also, retirement funds and pensions from different newly instituted professional categories with available funds devoted resources to medical and hospital care for their members as a strategy for the recovery of contributors and for the reduction of the load of early benefits paid for acquired disability.

By the 1930's, all of these initiatives had resulted in the reversal of the general tendency to a fall in the expectation of life, and the increasing trend of this measure became consolidated over subsequent decades in a relatively regular manner. A contributing factor was the reduction of immigration starting in 1934, when the decline of coffee trade determined a severe restriction of quotas of foreign immigrants. However, the need for expansion of the work force in the State of São Paulo continued to exist and was then satisfied by internal migration, which increased especially after 1927, encouraged by the prosperity of the State, by the industrialization process and by the lack of perspectives in other regions of the country, the Northeast in particular.

The new population contingent consisting of Northeastern migrants arrived on a smaller scale (in proportion to the larger population residing in the city at the time) and tended to settle with greater stability than the Europeans. Furthermore, this flow remained constant over subsequent decades, representing a different migratory profile compared to the earlier phenomenon[20]. This modification somehow contributed to the change of the demographic profile of the population for the city of São Paulo, as registered in this study, mainly through the reduction of the variance pattern of this measures, as observed for the rates and indicators recorded during this second period.

In addition to being reflected on the progressive inversion of the reduction of expectation of life, the new migratory profile was also reflected on a cycle of marked reduction of birth rate which extended from the mid-1930's to the end of the 1940's, with values always below the secular trend towards a reduction of this measure. A hypothesis that could be raised to explain this observation is that, whereas extended families were valued at the beginning of the century, the cultural patterns of the new migrant classes may have favored undernotification of births to the civil registry during the subsequent period. A fact supporting this interpretation is that the reduction in the birth patterns shown by the time-series related to birth rates was associated with a cycle of reduction in the population rates of legal unions, also observed in the 1940's by the civil registry.

The profile of the population movements that occurred during this period can also be measured by the evolution of the calculated juvenile and senile dependence ratios for the city of São Paulo. Whereas during the previous period the juvenile dependence ratio had decreased from the fantastic rate of 81.29 in 1900 (indicating the number of persons younger than 15 years per 100 adults aged 15 to 65 years) to 51.12 in 1934, the senile dependence ratio (number of elderly persons older than 65 years per 100 adults) increased from 3.03 to 5.26. From 1934 to 1970, these measures showed strong oscillations, indicating the unstable composition of the population, still subjected to the influx of a strong migratory process. The juvenile dependence ratio continued to decrease until 1950, when it reached a value of 42.99, only to advance again in 1960 (50.97) and 1970 (51.11), indicating that the intensification of internal migration at the end of this period may have been reflected by the proportion of young people in the population. In a complementary manner, the proportion of aged individuals decreased from the level obtained in 1934 to 4.64 in 1940 and 4.65 in 1950, regained the previous amplitude in 1960 (5.48) and grew even more in 1970 (6.22), when it probably demonstrated the results of an entire generation of progressive improvement in the expectation of life at birth.

Consolidation of the Population Profile: 1970-1994

In the years that followed 1970 - a period more intensely analyzed in recent demographic studies - the population movement reported here appeared to stabilize, with a progressive improvement of the general indicators of social development. The continued trend of average lifetime to advance was associated with a consistent fall in the infant mortality rate[21-27] after 1973, with an acute growth of the Swaroop and Uemura indicator[28] (from 46.2% in 1969 and 48.4% in 1970 to 62.6% in 1992, 62.5% in 1993 and 56.9% in 1994), and with a decreased proportion of stillborn infants in relation to the total number of births (from 2.4% in 1969 and 1970 to 0.8% in 1993 and 1994).

Also with respect to the evolution of the proportions between the large age groups in the populations, the tendency recorded seems to have reflected a perspective of a greater equilibrium compared to previous periods characterized by more marked variation. While the juvenile dependence ratio decreased to 43.28 in 1991, the senile dependence ratio increased to 7.77 as an

effect of the modification of the age profile of the population, something also easily verified in the population pyramids relative to more recent censuses that record the beginning of the replacement of the triangular format with the approximately rectangular format (at least for the younger age ranges) as a consequence of the reduction of the birth base and of the gradual overall aging of the population[29-32]: the so-called process of "demographic transition" had definitely begun.

The concomitant variation in the measures of social development indicates a definite progress in the general living conditions of the population residing in the Municipality of São Paulo during this period. By being a product of this progress, the similarity of these indications throughout the period may be interpreted as a successful determination of social development recorded for the period, as well as a sign of the consolidation of the population profile of the city, which no longer seemed to be subjected to the wide oscillations previously produced by the migratory processes, as registered by the time-series delineated in this study. Although they did not stop, the migratory movements involving the city of São Paulo reduced the proportion of their impact on the population as a whole, with their magnitude decreasing during this period, but also as a function of the enormous growth in the number of inhabitants in the metropolis in more recent times.

However, this agreement between the indicators of social development may also be interpreted, from another viewpoint, as a sign of the inability of these measures to reflect nuances of the variation of the new social processes, mainly the economic cycles of growth and recession to which the population was submitted during this third period of time in the study.

The years preceding 1973 came to represent the period of the "economic miracle" to the Brazilian population, i.e., years of wide expansion of the gross national product and of relative social well-being, at least for the middle stratum of the population. In contrast, the years that followed were marked by a recessive economy, by the growth of inflation and by the lack of investment in public services, from which a return of social benefits was expected. In a first phase, the country boasted about the continental expanse of its territory, its natural resources and even its national soccer team. The settlement of vast regions of low population density was proposed and efforts were made to promote territorial integration by opening highways that cut through the equatorial forest. In a subsequent phase, these roads were almost totally abandoned, as well as the populations served by them, while family planning and birth control campaigns[33-35] were implemented with greater intensity, indicating the difficulties in providing suitable living conditions for everyone.

This movement, which affected the country as a whole and also its largest city, did not produce appreciable signs in the time-series of expectation of life at birth, of infant mortality rate, of the Swaroop and Uemura indicator, or of the standardized mortality rate recorded for São Paulo. However, the same was not true for the series concerning the population rates of weddings and births, which appear to have reflected this factor, with the former showing an absolute increase in all years from 1967 to 1975, and the latter showing an increase from 1969 to 1982, with a subsequent decrease for both parameters.

These data favor the interpretation that the population of São Paulo conformed to the conditions prevailing at the time, with an increase in legal unions and birth rates when the resources seemed to be less scarce, and a decrease when the opposite was perceived.

Thus, one may state that the population movements represented by the cyclic variations in wedding and birth rates were more sensitive to the effects of the socioeconomic situation during the more recent period than the classical indicators of social development, and should be analyzed by using these measures whenever

there is a wish to promote studies of the characterization of demographic processes. Furthermore, the reduction of birth rates in recent years hastened the slow pace at which the demographic transition was being processed in the metropolis, making its effects more perceptible. And, since the forecast analysis of this measure indicates a future increase, possible difficulties in the continuity of the demographic transition process in the city may be predicted for the next few years.

Conclusions

1. Former signs of demographic transition in the Municipality of São Paulo can be traced to the middle of the century, by the time-series related to indicators of social development; therefore, later than in European and North American cities. This transition also developed at a slower speed, while the city was subjected to an intense migratory process and a cyclic movement of increase and decrease of birth rates.

2. The heteroscedasticity of the time-series related to social development is another indication of the demographic transition in the city, as the lesser variance of the values was closely attended by better measures for each series.

3. Many time-series registered outlier measures for 1918, showing the magnitude of the mortality due to the epidemics of influenza.

4. The model for the expectation of life at birth time-series revealed a consistent decrease for the measures from the beginning of the century to the mid-twenties, as an acute indication of social instability for the city during that period.

5. Forecast analysis of time-series related to average lifetime reinforces the trend of better indications for the next few years, a fact suggesting the improvement of the changing pattern of the populational profile in the city.

6. The log-linear model for the regression analysis of the birth rates time-series associated the increase of the measure with the increase of nuptiality, with the decrease of the infant death rate and the decrease of the proportional mortality ratio of Swaroop and Uemura.

7. The forecast analysis of birth rate time-series indicated an increasing trend, or, at least, the stability of the variable, as the most probable hypothesis for the next few years, a fact that may be threatening the continuity of the so called process of demographic transition in the city.

8. Up-to-date statistical procedures of time-series analysis proved to be powerful tools for research involving demographic measures. When applied to historical interpretation, quantitative methodology improves the formulation and selection of hypotheses, with a better understanding of the phenomena studied.

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