The relation between compositional changes of births and infant mortality decline in Brazil

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Introduction

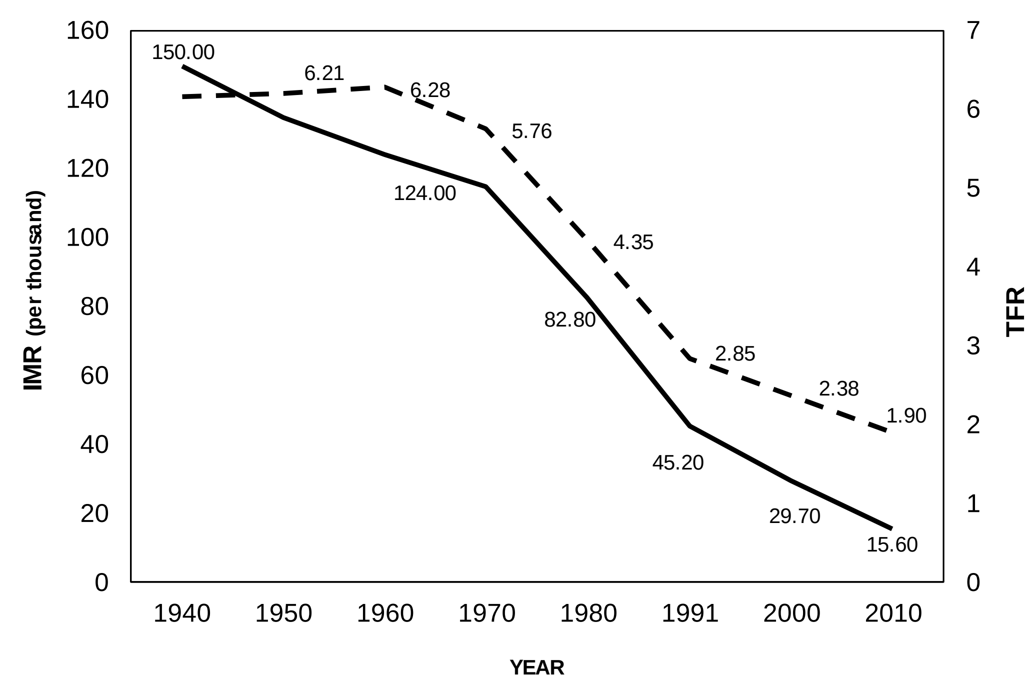
Over the last decades, infant mortality in Brazil has experienced a significant decline, varying from about 162 deaths per thousand in 1930 to 20 in 2010. This unprecedented reduction in the number of children dying under one year of age allowed life expectancy to increase steadily, changing from 34.6 years in 1910 to 73.5 years in 2010.

Most of the earlier studies that examined trends and patterns of infant mortality decline in developing countries have emphasized the roles played by improvements in sanitation and medical technology, the adoption of healthier habits, and the diffusion of health services through the expansion of the public health care system (Mosley and Chen 1984; Caldwell 2001; Palloni 1981). Many authors have also shown that mother's education is a key factor underlying infant and child mortality differentials (Caldwell 1979; Das Gupta 1990; Caldwell and McDonald 1982; Hobcraft et al. 1985; Sastry 2004; Victora et al. 2000). The vast majority of these studies have benefited from the increasing availability of micro data, particularly DHS and census data, to examine how individual, household and community variables are associated with the chances of dying in the first years of age. After many decades of research, we can assert with no hesitation that the determinants of child survival in developing countries are firmly established in the literature.

Research on the determinants of infant mortality rates (IMR) in Brazil is also abundant and has a long history. Earlier studies have shown substantial regional variation in infant mortality rates during the 1940s and 1950s, with children in the northeastern region facing the highest mortality levels (Carvalho 1974). More recently, Castro and Simões (2009) showed that the significant decline in IMR over the last four decades, although geographically pervasive, did not change much the historical patterns of regional concentration of infant mortality outcomes. Other authors have looked more closely at the rural-urban gap in IMR. Until the late 1970s, the gap proved to be small or inexistent, particularly within groups of lower SES (Carvalho and Wood, 1978; Merrick, 1985). However, with the improvement in the living conditions, substantially lower infant mortality rates in the urban areas have emerged (Sastry 1997, 2004). The regional disparities in infant mortality in Brazil arise from differences in the most well knows factors such as household income, mother's educational attainment and age, birth order, and availability of water supply, sanitation, electricity, and health facilities (Sastry 1997, 2004; Barros and Sawyer, 1993; Sastry, Goldman and Moreno, 1993; Lima 2013).

Although the determinants of IMR in Brazil have been examined comprehensively, the proliferation of high quality individual data has precluded scholars for looking at more simple questions, including the relationships that connect changes in the composition of births with the time evolution of infant mortality decline. It is not surprising that fertility levels have declined alongside the reduction in infant mortality rates in Brazil (Figure 1) as a result of the demographic transition. But not only fertility levels have changed drastically, either educational differentials in fertility have reduced. A large part of the recent variation in the total fertility rate in Brazil has been due to both declining specific fertility rates among the lower education groups and the smaller proportion of mothers of lower SES (Rios-Neto and Guimaraes 2013). Back in the 1940s, only 25 percent of the children aged 7 to 14 years were enrolled in school. Currently, nearly all children attend school, and positive advances in attendance rates have been also documented for children aged 15-17 years and tertiary education (Rios-Neto and Guimaraes 2010). Changes in the education profile have affected women more notably than men.

Figure 1 - Infant Mortality Rate and Total Fertility Rate, Brazil, 1940 to 2010



Source: IBGE (Brazilian Bureau of Census)

Therefore, one should expect a relatively lower proportion of births originating in population subgroups with higher risks of dying under one year of age. We are aware of only some studies that looked at the association between the composition of births and IMR in Brazil. Back in the early 1990s, Beltrao and Sawyer (1991), followed by McCracken, Rodrigues and Sawyer (1991), and Barros and Saywer (1993), estimated the extent to which regional variations and gains in infant mortality rates, during the mid- 1970s and 1980s, were due to changes in the composition of births. More recently, Ribeiro and Rodrigues (2004) used data from the 1996 DHS to compare standardized mortality rates in the Northeastern region with the rest of the country. All these articles showed that composition changes mattered for variations in infant deaths during the period of analysis, although only partially. Our objective in this study is to advance our understanding on this relationship by covering a substantially longer period of time, which has been characterized by major changes in the education profile of the Brazilian female population. We use a simple method to examine the extent to which changes in the proportionate distribution of births by mother's age and education explain the remarkable decline in infant mortality between 1970 and 2010. We also speculate about further potential declines in IMR from future changes in the distribution of births due to better maternal education.

METHODS

Let *D* be total deaths of children under one year of age and *B* the total number of births during the same year. Thus, the infant mortality rate is:

$$\mathrm{IMR} = \frac{\mathrm{D}}{\mathrm{B}} \tag{1}$$

As noted above, infant mortality rates vary according to different maternal characteristics. We want to look specifically at the effects of changes in the composition of births by mother's age and education. Therefore, we replace deaths by the sum of products of births ($B_{i,j}$) and infant mortality rates (*IMRi,j*) by mother's age group *i* and education level *j:*

$$\begin{aligned}\mathrm{IMR} &= \frac{\sum_{j=1}^{n}\sum_{i=15;5}^{45}\mathrm{IMR}_{i,j}\times \mathrm{B}_{i,j}}{\mathrm{B}} \\ &= \sum_{j=1}^{n}\sum_{i=15;5}^{45}\mathrm{IMR}_{i,j}\times \mathrm{b}_{i,j}\end{aligned} \tag{2}$$

Equation (2) says that the infant mortality rate can be rewritten as a weighted average of age-education specific infant mortality rates, where the weights are provided by the proportionate distribution of births ($b_{i,j}$) by mother's age and education. In order to control for differences in the distribution of births over time, we standardize the effects of differences in the distribution of births by mother's age and education between 1970 and 2010. The age-education standardized infant mortality rate in year *t* is:

$$\mathrm{AESIMR}^{t} = \sum_{j=1}^{n} \sum_{i=15;5}^{45} \mathrm{IMR}_{i,j}^{t} \times \mathrm{b}_{i,j}^{S} \qquad (3)$$

The choice of the standard population distribution is a known methodological issue that restricts the applicability of the standardization method. It can affect both the direction and the magnitude of the difference between the rates being compared (Preston et al. 2001). Here, we are interested to answer a "what if" type of question by asking what would happen to the infant mortality rate in 1970 under a scenario of distribution of births by mother's age and education as observed in 2010, and vice-versa. Therefore, the choice of the standard proportionate distribution of births is implicitly determined by the counterfactual research question we are addressing in this article.

The difference between the actual and the counterfactual rates provides us with the net effect of changes in the proportion of births from mothers pertaining to different age and education subgroups in Brazil under the assumption of constant mortality differentials. In addition to comparing the IMR in two distinct periods of time, in our last counterfactual simulation, we ask what would happen to the infant mortality rate in 2010 under a scenario of distribution of births by mother's education as observed in the state of Massachusetts in 2010. We expect with this stylized exercise to provide some clues about the limits of compositional effects for future infant mortality gains in Brazil.

DATA

To estimate age and education specific infant mortality rates for 2010, we obtain data on deaths from the Mortality Information System of the Ministry of Health (SIM/Datasus). The SIM is an administrative database that contains information from individuals who died since 1979 in Brazil. Besides age, measured in five year age groups from 15 to 49, we categorize education according to three groups: less than completed primary, primary completed, and at least secondary completed. Unfortunately, the low number of cases precludes us from disaggregating the highest education level. To correct for possible under registration of deaths we estimate the total IMR as the weighted average of age and education specific infant mortality rates for 2010 and compare with the official estimate from the Brazilian Bureau of Census, which is calculated based on indirect techniques and census data. We use the ratio of the IMR official estimate and the SIM estimate to correct our age and education- specific infant mortality rates proportionally.

In the absence of mortality registration data and census data on age-education-specific infant mortality rates for 1970, we assume the rates in 1970 to be proportionally higher to the set estimated for 2010, when performing the standardization. This simplifying assumption is not unrealistic for Brazil, despite rapid mortality changes, as has been shown in earlier studies (e.g. Sastry 2004). Later, we will discuss more about the possible consequences for our conclusions of that assumption not holding.

To calculate the proportionate distribution of births by mother's age and education in 1970 and 2010, in a consistent way, we follow two steps. First, we apply the P/F ratio Brass method to census data on the number of children ever born and the number of children born during the year preceding the census (IPUMS 2013) to calculate age-education specific fertility rates. We then combine these rates with the distribution of women by age and education to obtain the distribution of births. Data for births by maternal education in Massachusetts come from the MA Department of Public Health (2013).

RESULTS

In Table 1, we describe the proportional distribution of births by mother's age and education in Brazil for the census years 1970, 1991 and 2010. The first panel shows that births have become concentrated at younger ages over time. In 1970, 80.3% of births were from mothers aged 15 to 34. In 2010, this proportion increased to 88%. This change is not surprising given the reduction in the number of children ever born in Brazil. Nevertheless, the increasing concentration of births at the youngest age group (15-19) is a salient finding that has been reported elsewhere (Berquo and Cavenaghi 2004). Another striking result is the substantial change in the proportion of births by mother's education. In 1970, 95% of births were from women with less than primary completed. In 2010, there was a sharp decline in the proportion of births from mothers in the lowest education group (25.4%) and an increase of about 18 times in the proportion of births among women in the highest education group (from 1.5% to 27.8%).

Table 1 - Proportional Distribution (%) of Births by Mother's Age and Education, Brazil, 1970, 1991 and 2010

Age	1970	1991	2010
15 to 19	8.6	14.1	17.0
20 to 24	27.6	30.5	29.1
25 to 29	25.4	26.7	25.1
30 to 34	18.8	16.0	16.7
35 to 39	12.8	8.4	8.6
40 to 44	5.6	3.4	2.8
45 to 49	1.3	0.8	0.5
Education	**1970**	**1991**	**2010**
Less than primary completed	95.0	65.9	25.4
Primary completed	3.5	23.6	46.8
At least Secondary completed	1.5	10.6	27.8

The differences in the distribution of births between 1970 and 2010 are a product of changes in the age specific fertility rates and in the age distribution of women by education. Figures 2 and 3 demonstrate a large reduction in fertility differentials by education. For example, in 1970, the fertility rate for women with less than primary completed in the age group 25-29 was 3.47 times higher than the rate for women with secondary completed. In 2010, this ratio reduced to 2.7 times. At same time, the proportion of women in the lowest education group reduced from 85.5% to 14.6% (ages 25-29). This major change in the education profile of women occurred across all age groups with the larger differences being among the youngest cohorts, which is not surprising given that the education transition accelerated only recently in Brazil. Overall, the proportion of births from mothers in the lowest education group reduced from between 93.9 and 98.6% in 1970, depending on the age group, to between 21.1 and 56.6% in 2010.

Figure 2 - Age-Specific Fertility Rates and the Proportional Age Distribution of Women and Births by Education Groups, Brazil 1970

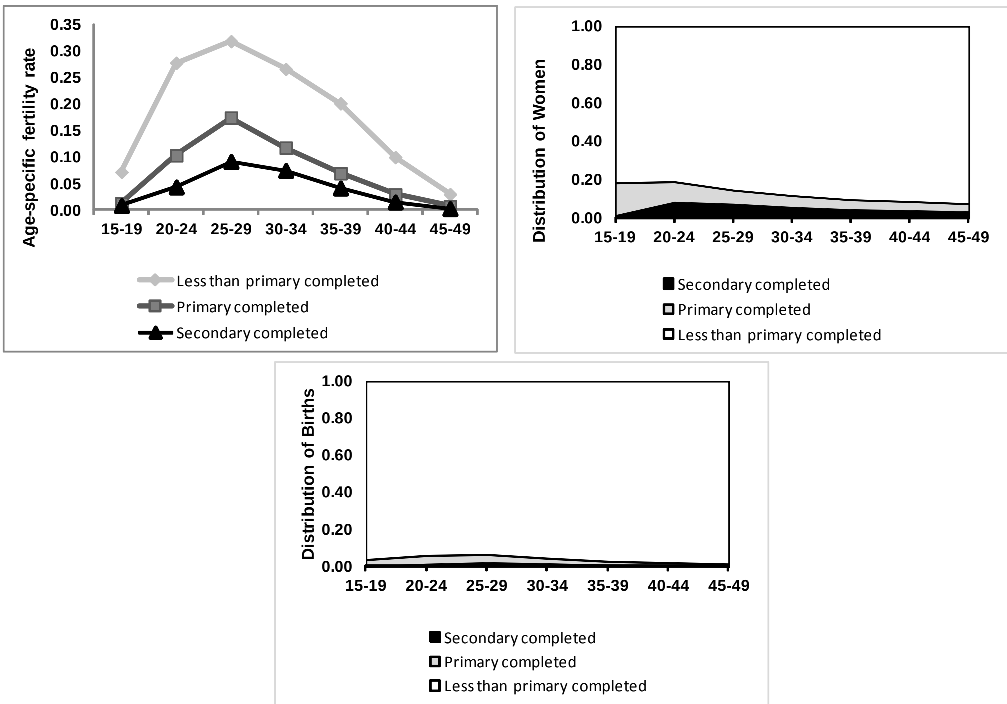
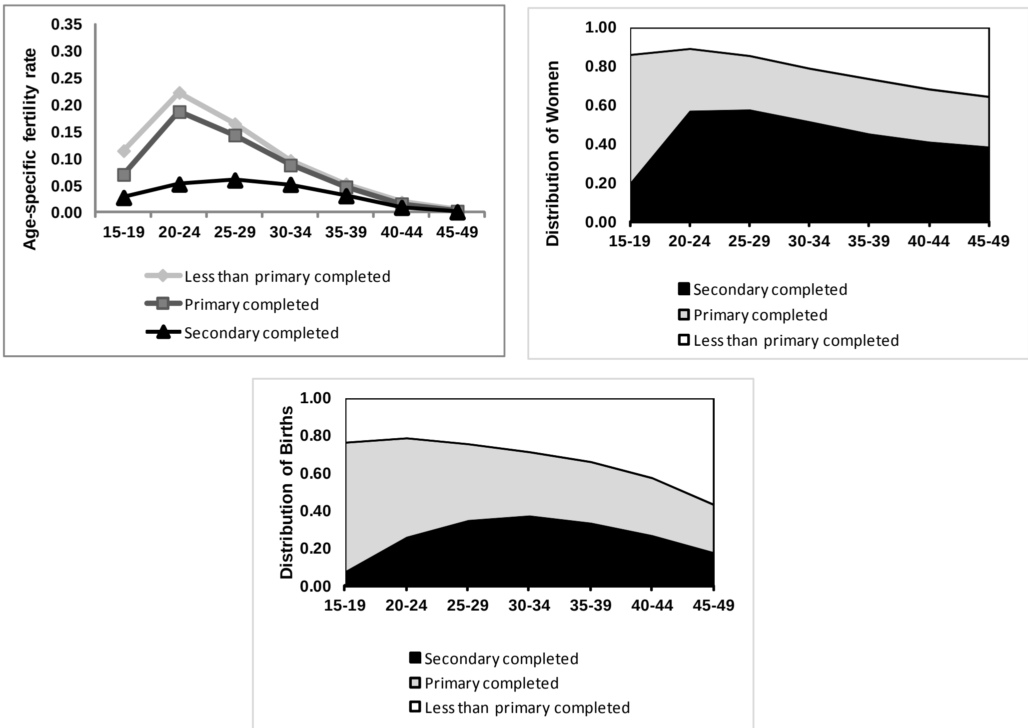


Figure 3 - Age-Specific Fertility Rates and the Proportional Age Distribution of Women and Births by Education Groups, Brazil 2010



As shown in the first panel of Table 3, infant mortality rates vary significantly by education group in 2010. The ratio of the mortality rates for births in the lowest and the highest maternal education group varied, by age group, from 1.10 to 2.15. Among women aged 25 to 29 years old, where most of the births occurred (37%) in 2010, the risk ratio was equal to 1.71. There is also some variation by age (Lima et al. 2010) with the highest mortality rates for children born to the youngest (15-19) and the oldest mothers (40 and above). But births from these age groups represented only 20.4% in 2010. By construction, the mortality differentials in 1970 are the same as in 2010, although mortality levels are, of course, higher.

Table 2 - Infant Mortality Rates by Mother's Age and Education, Brazil, 1970 and 2010

2010

Age	Less than primary completed (1)	Primary completed	At least secondary completed (2)	Ratio (1) /(2)
15-19	20.79	14.33	12.95	1.61
20-24	18.05	11.67	10.95	1.65
25-29	16.72	10.23	9.79	1.71
30-34	17.34	10.31	8.37	2.07
35-39	21.22	12.70	9.85	2.15
40-44	25.43	17.16	15.15	1.68
45-49	29.47	14.79	26.70	1.10

1970*

Age	Less than primary completed (1)	Primary completed	At least secondary completed (2)	Ratio (1) /(2)
20-24	112.65	72.84	68.32	1.65
25-29	104.33	63.84	61.08	1.71
30-34	108.24	64.32	52.20	2.07
35-39	132.42	79.25	61.48	2.15
40-44	158.67	107.08	94.57	1.68
45-49	183.93	92.32	166.59	1.10

*Assuming the same mortality differentials by age and education in 1970 as of 2010

The combination of changes in the distribution of births with large mortality differentials by age and education results in major compositional effects. According to Table 3, IMR varied significantly between 1970 and 2010: from 115 per thousand to 15.6 per thousand; a decline of about 86.4%, saving more than 99 children per thousand births. The standardized rate for 2010 suggests that changing only the distribution of births to the 1970 patterns, while holding mortality constant at the 2010 levels, would have increase the current IMR by 40.4% (Table 3). This figure is not trivial since it represents about 6.31 deaths per thousand, a number as large as the current infant mortality level in several developed countries.

Table 3 - Comparison of crude infant mortality rates and standardized infant mortality rates, using different distributions as standard, Brazil

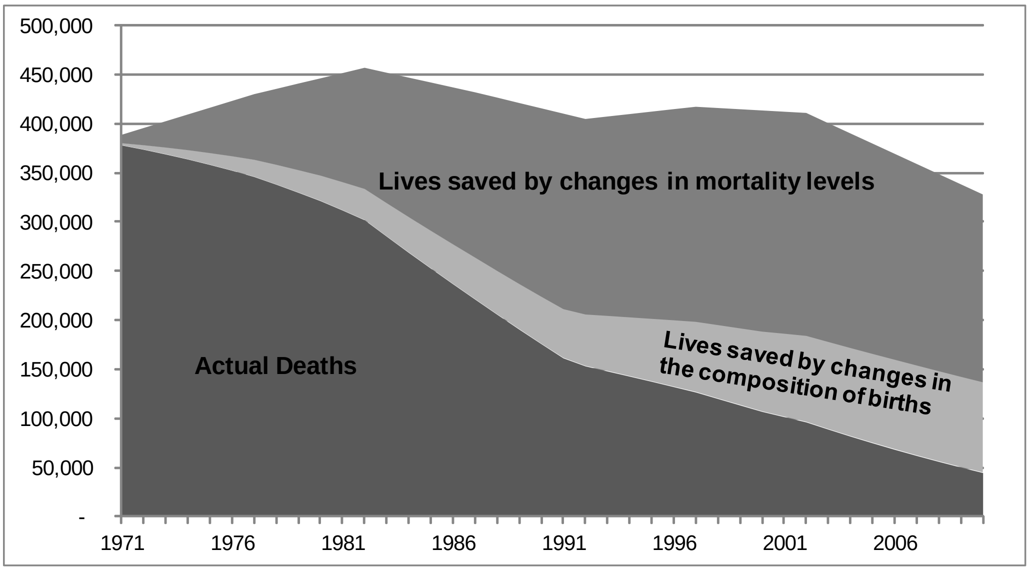
IMR Brazil 1970	115.00
IMR Brazil 2010	15.60
Absolute Difference (per 1000)	99.40
Brazil 2010 standardized using the distribution of births by mothers' age and education as of 1970	21.91
Absolute Difference (per 1000) with respect to 2010	6.31
Relative Difference (%) with respect to 2010	40.42
Brazil 1970 standardized using the distribution of births by mothers' age and education as of 2010*	82.67
Absolute Difference (per 1000) with respect to 1970	(32.33)
Relative Difference (%) with respect to 1970	39.10
Brazil 2010 standardized using the distribution of births by mothers' education as of Massachusetts 2010	12.29
Absolute Difference (per 1000) with respect to 2010	(3.31)
Relative Difference (%) with respect to 2010	26.96

***Assuming the same mortality differentials by age and education in 1970 as of 2010

It is very implausible that the 2010 rate will deteriorate because of a more unfavorable distribution of births by mother's age and education. Therefore, we reversed the question to look at how much of the decline in IMR between 1970 and 2010 was due to the more favorable distribution of births over the four decades. Since we have assumed proportionally higher age-education infant mortality rates in 1970 as of 2010, it is not surprising that the relative effect of compositional changes is similar to the one in the first simulation. However, the absolute difference turns out to be much larger (about 32.33 deaths per thousand births) since mortality levels were significantly higher in 1970.

One related question is how many Brazilian children born between 1970 and 2010 were saved because of improvements in mortality levels and changes in the composition of births. We interpolated the distribution of births by age and education annually, between the census years 1970 and 1991, and after that, between 1991 and 2010, to standardize the 1970 IMR according to each distribution every year. We then compared the actual number of deaths every year with the expected number of deaths calculated under the actual and standardized 1970 IMRs. The results indicate that the accumulated number of deaths for the entire 1970-2010 period would have been almost twice as large (16.8 MM compared to 8.42 MM) if IMR had not declined. Out of the 8.42 MM lives saves, about 2.08MM were due to changes in the composition of births. According to Figure 4, the number of lives saved because of compositional changes of births has increased in more recent years (1.56 MM of lives saved occurred from 1991 to 2010), which it is a consequence of both converging fertility rates across education groups and a better education profile of mothers since the re-democratization of Brazil in 1986.

Figure 4 - Actual Number of Infant Deaths and Estimated Number of Infant Lives Saved, Brazil 1970-2010



Is there still room for additional declines in the IMR as a result of future improvements in the education profile of Brazilian mothers? We standardize the 2010 IMR in Brazil based on the distribution of births by mother's education observed in the

State of Massachusetts in 2010, with the implicit assumption that the Brazilian female population will achieve the MA current education profile. Table 3 shows that the IMR could reduce another 27% (about 3.3 deaths per thousand births) reaching 12.2 under the MA distribution assumption. Since we were not able to break down the distribution of births into smaller education groups, including the tertiary, we expect our estimates to be underestimated, and the true upper limit of the composition effects to future infant mortality gains to be probably higher.

Discussion

In this article we provide the plausible pure effects of compositional changes in the distribution of births by mother's age and education on the Brazilian infant mortality rate. As we showed in our simulations, changes in the distribution of births have contributed significantly to the improvements in infant mortality levels in Brazil, mostly because of major changes in the education profile of mothers. The IMR in 1970 would have been 39% lower if the distribution of births were similar to the one in 2010. Between 1970 and 2010, about a quarter of lives saved (more than 2MM children) were due to more favorable distribution patterns. Of course, our results also revealed that the rapid and substantial decline in the IMR happened mainly because of significantly lower mortality risks across all population subgroups. Out of the total lives saved, three quarters were due to improvements in mortality levels, regardless of changes in the distribution of births by socioeconomic status.

Our findings have at least one important policy implication. It shows that in unequal societies like Brazil, where homogeneous mortality risks are still an unachievable goal, providing more and better education can help reduce mean infant mortality levels. In the case of Brazil, there is certainly room for further mortality declines, even if they come only from inertial advances in the education profile of mothers, as more educated female cohorts replace the old ones. At the same time, since there is still a long way to go until the education profile of the Brazilian population becomes comparable to those in the most rich countries, promoting reproductive rights can save infant lives by reducing unintended pregnancies in the lowest SES groups.

With regard to the methodological limitations of our study, one should note, first, that our counterfactual simulations measure only the first order effects of composition changes. We did not take into consideration any inter-relations among the demographic and socioeconomic variables with mortality levels. We believe such feedback effects exist, however. In addition, lack of historical data limited our analysis from decomposing births and death rates by a larger number of proximate determinants of IMR. Yet, our hypothesis is that any changes in the composition of births according to these other determinants are probably positively correlated with changes in the education profile of mothers, and should not add much to our understanding of the overall decline in IMR in Brazil.

It is true, however, that the improvement in the education profile of the Brazilian population is a recent phenomenon, and its implications for mortality variance and levels need a more detailed examination. Education mobility may have modified the population composition with respect to other observable and unobservable characteristics that affect mortality variance within the education groups. If so, our analysis may have been hiding other compositional effects. In results not shown here, we used census microdata to calculate a child mortality index (ratio of observed to expected deaths) for each observation in 1970 and 2010 (Preston and Haines, 1991) and compared the variance of the index by education and age groups for the two years. We found that the variance has increased, which suggests that the effect of changes in the education structure on mortality levels may have been buffered by other compositional changes; a results that needs further analysis.

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