Supplementary appendix Infant mortality in Venezuela: A systematic analysis of demographic data Supplementary Material

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Supplementary appendix

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Infant mortality in Venezuela, a humanitarian crisis under way: A systematic analysis of demographic data

Supplementary Material

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1. Estimating infant mortality rates

Calculating infant mortality rates requires computing death counts in the population under one-year old as well as live births during the same period. In order to provide long-term infant mortality estimation, three sets of infant mortality rates (IMR) were approximated in this study. In Venezuela, there are only two official producers of mortality and demographic data: Venezuela Ministry of Health (VMH) and the Venezuela National Institute of Statistics (VNIS). IMR grouping depended on the available mortality database for its computation as did the applied estimation method . The first group were IMRs calculated using *Official mortality statistics* corresponding to the period 1985 to 2013. The second group calculated through adjusted death counts published in the *Notifiable Diseases Bulletins* for the years 2003 to 2016. Finally, a third group of estimations obtained through indirect methods on *other demographic databases*. All IMRs were later synthesized and smoothed by a P-Splines model into a long-term estimation.

1.1. Official mortality statistics

IMRs were directly calculated through official death counts published by the VMH and reported by the World Health Organization (WHO). Deaths for which a medical certification had been issued are listed in VMH's mortality yearbooks. Deaths with medical certification significantly increased during the 1970s to more than 90% of all deaths. This increase continued, and at the beginning of the 2000s only 0.3% of all deaths lacked medical certification.[1] PDF files of mortality yearbooks until the year 2013 were available online on VMH's official website until 2016.

Annual reported deaths coming from the Venezuelan vital statistics system had data of reliable quality and almost complete coverage until the first decade of the twenty-first century. [2] At the beginning of the 1980s, the proportion of under-coverage was already estimated at less than 10% [3] and continuous improvements placed it at 2.4% during the first decade of the twenty-first century.[4]

Two IMR time series were estimated using official death counts. The first set of estimations considered birth counts held as reference by VMH for producing its official infant mortality rates.[5] We relied on the availability of these adjusted counts to produce IMR from 1985 to 2009. However, some issues arose concerning this data. The assumptions taken for the adjustment could not be found in any technical document published by VMH. In addition, some figures were still needed for the most recent years (2010–2013). We calculated a second set of IMR estimations for the period 1985 to 2013. This time, the denominator came from the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) birth records [6] published in 2016. ECLAC's estimations cover the period 1950 to 2100. These long-term figures are updated through household and population census data. The latest census taken in 2011 [7] allowed ECLAC to review recent trends in fertility patterns. Both sets are displayed in Table 1.

Some differences were found when comparing results. Setting VMH's birth counts as the benchmark to compute the proportional difference was possible to evince an over-estimation of ECLAC's figures. From 2005 on, the trend changed, and births used by VMH progressively increased, compared with those adjusted by ECLAC according to 2011 census findings. Because the two time series were built with official statistics without strong reasons to disregard either of them, they were both considered.

1.2. Notifiable Diseases Bulletins data

Because no mortality data have been published officially since 2013 in Venezuela, we estimate IMR from 2013 to 2016 using direct methods on adjusted death and birth counts. Deaths came from the weekly Notifiable Diseases Bulletins (NDB).[8] Since the year 2003, NDB has incorporated death counts of children under one year old along with death counts associated with pregnancy, childbirth and the puerperium conditions occurring health-system facilities. NDB were not usually available for the general public. Instead, the Morbidity Yearbooks summarized data related to some specific diseases. In May 2017, weekly NDB corresponding to the years 2003 to 2016 were briefly released on the VMH's official website. [9] We took the weekly facilities-reported death counts, and adjusted them to approximate the total number of deaths having occurred or not in the health system.

For this second set of estimations, we also adjusted reported birth counts published by the VNIS[10] to capture the most recent trends in fertility. We expect that fertility patterns have been as affected by the crisis as mortality has. In both cases, we estimated counts relying on the assumption that registration and reporting pattern remained the same despite the crisis. We acknowledged that this assumption can be rejected due to the deep socioeconomic crisis that has correspondingly affected public institution performance, which could result in diminishing the quality of the registration and its coverage. However, being unable to prove and measure the change, we took the risk and produced more conservative estimations.

Table 1: Infant mortality rates considering official mortality statistics.

Year	Official Death counts	Births		Infant Mortality Rates		% Difference in IMR
		ECLAC	VMH	ECLAC's births	VMH's births	
1985	13517	525983	502329	25.7	26.9	4
1986	13028	530781	504278	24.5	25.8	5
1987	12823	535578	516773	23.9	24.8	4
1988	11867	540376	522392	22.0	22.7	3
1989	12976	545173	529015	23.8	24.5	3
1990	14776	549970	573501	26.9	25.8	-4
1991	12394	554768	592785	22.3	20.9	-7
1992	12327	559565	560994	22.0	22.0	0
1993	12494	564362	524387	22.1	23.8	7
1994	13577	568840	547819	23.9	24.8	4
1995	12352	569165	520584	21.7	23.7	9
1996	11913	569490	497975	20.9	23.9	13
1997	11069	569815	516636	19.4	21.4	9
1998	10721	570139	501808	18.8	21.4	12
1999	10108	570464	527888	17.7	19.1	7
2000	9649	570789	544416	16.9	17.7	5
2001	9353	571114	529552	16.4	17.7	7
2002	8949	571438	492678	15.7	18.2	14
2003	10276	571763	555614	18.0	18.5	3
2004	9272	572088	530565	16.2	17.5	7
2005	9093	572413	585655	15.9	15.5	-2
2006	8371	572738	588500	14.6	14.2	-3
2007	8323	573062	591345	14.5	14.1	-3
2008	8307	573387	594191	14.5	14.0	-4
2009	8577	573712	594300	15.0	14.4	-4
2010	8965	574037		15.6		
2011	8900	574361		15.5		
2012	8881	574686		15.5		
2013	8757	575011		15.2		

1.2.1. Adjusting death counts

Given that the main aim of the NDB is not to report all death counts, but only those occurring in health system, its annual summary has systematically underestimated counts in mortality yearbooks. We modelled this underestimation as a statistical relation to project deaths for the period 2014 to 2016, again assuming the continuity of the previous reporting pattern.

We established a ratio between death counts from mortality yearbooks and those in NDB during the years 2003 to 2013. This underestimation ratio was linearly related to time, and it was possible to express this as Underestimation ratio=-0.0532year+1.8694. Thus, we corrected under-reported deaths from the NDB counts through a linear prediction of the ratio. Our result in Table 2 revealed that death counts reported in the NDBs represented from 81.2% to 88.9% of the deaths that would have been reported in the mortality yearbook.

1.2.2. Adjusting births counts

Registered births gathered and published by the VNIS [10] were adjusted to estimate IMR. VNIS has made available online registered birth data including the year of their occurrence only up to the year 2012. After this period, only the year of registration is given.

To distinguish occurred births by calendar year from registered births, we followed the cumulative time lags in registered births for a twelve-year period (2000 to 2012), and we created a Proportional Factor (PF) for each year. Our results showed that there was a six-year-delay to achieve 99% or more of occurred births to be registered.

Based on previous computations, we adjusted occurred births from 2006 to 2012. Adjustment of births occurred in year y (B_y^o) was made by taking into account births occurred and registered in the same year B_y^r plus the proportion of unregistered births calculated from the proportional factor

$$B_y^o = B_y^r + \left(B_y^r * \left(1 - PF_{2012-y}\right)\right).$$

Once all known information was complete, we established an annual registration/occurrence ratio. The average of the last three years-with-information ratio (2009 to 2011) was applied for the last four years in which no information related to year of occurrence is found (2013 to 2016). Results are shown in Table 2. We chose the average of the ratio because there was not any linear statistical significant relation to establish.

Table 2: Infant mortality rates considering adjusted birth and death counts.

Year	Deaths				Births					IMR
	Mortality Yearbooks	Notifiable Diseases Bulletin NDB	Under estimation ratio	Adjusted deaths	Registered	Occurred	PF	Registration/ Occurrence ratio	Adjusted births	
2000	9649				544416	554987	1.00	1.0	554987	
2001	9353				529552	534785	1.00	1.0	534785	
2002	8949				492678	488678	1.00	1.0	522885	
2003	10276	5810	0.56	10276	555614	523627	1.00	1.1	523627	19.6
2004	9272	5444	0.58	9272	637799	509979	1.00	1.3	509979	18.2
2005	9093	5084	0.55	9093	665997	514784	1.00	1.3	514784	17.7
2006	8371	6104	0.72	8371	646225	531760	0.99	1.2	534471	15.7
2007	8323	4745	0.57	8323	615371	531151	0.99	1.2	534564	15.6
2008	8307	5187	0.62	8307	581480	538848	0.99	1.1	543808	15.3
2009	8577	5083	0.59	8577	593845	537148	0.99	1.1	544548	15.8
2010	8965	5839	0.65	8965	591303	542856	0.98	1.1	555825	16.1
2011	8900	5873	0.65	8900	615132	542164	0.97	1.1	559770	15.9
2012	8881	7009	0.78	8881	619530	474020	0.85	1.3	563772	15.8
2013	8757	8273	0.94	8757	597902			1.1	559738	15.6
2014		8005	0.81	9852	597773			1.1	559617	17.6
2015		8812	0.84	10377	600875			1.1	562521	18.4
2016		11443	0.87	12866	600746			1.1	562401	22.9

1.3. Other demographic databases

A third group of IMR estimations was obtained through indirect methods on census data from the 1990, [11] 2001[12] and 2011[7] census round, carried out by VNIS and the recent National Survey of Living Conditions of Venezuelan Population ENCOVI-2016. [13] In addition, just two Demographic and Health Surveys have been carried out in Venezuela during this period: Venezuela Population and Family Survey (ENPOFAM 1998)[14] and Venezuelan Demographic Survey ENDEVE (2010-2011)[15]. Neither of them were considered in this analysis. The ENPOFAM-1998 survey covered a period in which we already relied on reliable quality data, and the ENDEVE-2010-2011 is not available to the public. So far, we covered all sources publicly available in the country regarding mortality data.

Census data and ENCOVI-2016 gleaned information about the number of children ever born and children still alive, by women's age. This information is known as Summary Birth Histories (SBH). Since SBH does not provide enough data on precise exposure times for direct calculation of IMR, we used this summarized information to apply Brass' model-based method to estimate IMR. Brass' model-based method converts the proportions of children ever born and dead by women grouped by age into a standard life table function by adjusting fertility and mortality model age patterns. The analysis was performed considering an average exposure-time indirectly approached from mothers' age. [16] Then, the probability of dying $q_{(0)}$ depends on mother's age($M_{(x,5)}$) and the proportion of dead children ($D_{(x,5)}$)

$$q_{(0)} = M_{(x,5)} * D_{(x,5)}$$

Here, we specifically used Trussell's variant of Brass's method. This variant calculates multipliers to transform proportions of dead children into cohort-specific probabilities of dying through regression approach. [17] This method gives retrospective mortality information, so it is possible to estimate from the SBH data infant mortality levels for a period of about 15 years prior to data collection._For all estimation west model of Coale-Demeny life tables were considered. Results are in Table 3.

Table 3: Infant mortality rates indirect methods on others demographic databases

Year	Census 2011	Census 2001	Census 1990	ENCOVI 2016
1985				
1986			31.3	
1987		31.8		
1988			33.9	
1989				
1990		29.3	39.7	
1991				
1992		27.3		
1993				
1994				
1995		26.4		
1996				
1997	19.6	27.1		
1998				
1999		29.3		
2000	17.6			
2001		27.0		22.3
2002	15.6			
2003				
2004				13.1
2005	15.2			
2006				
2007	14.5			
2008				
2009	14.6			
2010	14.3			
2011				
2012				
2013				22.0

Brass's method is traditionally used for countres with deficient vital registration systems. Some assumptions underline the Brass method and its variants; the most important is that fertility and infant mortality have remained constant in the recent past. Changes in fertility patterns could not be captured by ratios of average parities obtained from cross-sectional data. Consequently, no fertility experience of any cohort of women could be replicated, and the method could not provide an adequate index of the distribution in time of the births.[16] Breaking up the assumption of stability generates some problems in the results obtained. Analysis based on demographic micro-simulations showed how the Brass method has a tendency to overestimate mortality levels as well as produce declining rates once assumptions are violated. The studies indicated that overestimation of IMR is 15% on average in Latin American countries.[18]

2. Estimating long-term infant mortality rates

Pursuing the aim to smooth and synthetize, all previous IMR estimations were combined in a p-splines model. This model allows eliminating irregularities in the series introduced by the combination of several data sources and methods of adjustment, without losing possible changes in the pattern. [19] We intended to estimate not necessary the most exact IMR but for sure the most plausible ones due to the available estimations in the country. Our long-term estimation from 1985 to 2016 is shown in Table 4.

The p-spline method uses the independent variable to build a base for the regression. Later on, by introducing a penalty based on differences between adjacent coefficients, the likelihood function of the model is modified. To apply the p-splines method requires selecting the degree and location of the nodes *k*, it means the function that will build the base and the form of penalty *y*. [20] To generate the base, we used the cubic thin plate, because it was the base that, in terms of the variance of the estimates, showed best fit to the data. The function thus is expressed as a mixed model:

$$y_i = f(x_i) + \varepsilon_i, \quad \varepsilon_i \sim N(0, \sigma_\varepsilon^2)$$

Where, y_i refers to IMR previous estimation and x_i to the years, while ε_i to the error. The number of knots *k* and their places k_k were automatically selected using the expressions:

$$K = min\left(\frac{n}{4}, 20\right).$$

In which *n* is the number of IMR previous estimations inserted in the model and $k_K = \left(\frac{k+1}{K+2}\right)$ th simple quantile of the unique x_i.

Then f(x) is given by:

$$f(x) = \beta_0 + \beta_1 x + \sum_{k=1}^{K} u_k \left(|x - k_k|\right)^3$$

With the random effects *u*:

$$u = [u1. \dots .. u_k]^T \sim N\left(0, \sigma_u^2 \Omega^{-1/2} \left(\Omega^{-1/2}\right)^{\mathrm{T}}\right)$$

and Ω:

$$\Omega = \left[\left(\left|k_{\mathrm{k}} - k_{\mathrm{k}'}\right|\right)^3{}_{1 \leq \mathrm{k,k'} \leq \mathrm{K}}\right]$$

The smoothing parameter was selected as the quotient of random effects variance and fixed effects variance, $\sigma_u^2/\sigma_\varepsilon^2$ which was calculated using the restricted maximum likelihood method. The assumptions of this model are the same that underlie the mixed linear models:

i) $u \sim N\left(0, \sigma_u^2 \Omega^{-1/2} \left(\Omega^{-1/2}\right)^{\mathrm{T}}\right)$

ii) $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$

iii) $COV(u, \varepsilon_i) = \begin{bmatrix} \sigma_u^2 \Omega^{-1/2} \left(\Omega^{-1/2}\right)^{\mathrm{T}} & 0 \\ 0 & \sigma_\varepsilon^2 \end{bmatrix}$

Intervals of confidence were calculated at 90% and they were obtained through:

$$\hat{f}(x) \pm z\left(1 - \frac{\alpha}{2}\right) \hat{\sigma}_\epsilon \; st.dev\{\hat{f}(x) - f(x)\}$$

Where,

$$st.dev\,\{\hat{f}(x) - f(x)\} = \hat{\sigma}_\epsilon \sqrt{C(C'C + \frac{\hat{\sigma}_\epsilon}{\hat{\sigma}_u} D)C'}$$

$$D = \begin{bmatrix} 0_{2x2} & 0_{2xK} \\ 0_{Kx2} & \left(\Omega^{1/2}\right)^{\mathrm{T}}\left(\Omega^{1/2}\right) \end{bmatrix}$$

$$C = [1, x_i, |x_i - k_k|^3 {}_{1\le \mathrm{k} \le \mathrm{K}}]_{1 \le i \le n}$$

To apply the model we used the R package SemiPar. This package contained functions for semi-parametric regression analysis; it was developed by Matt Wand (2003).[21]

Table 4: Long-term Infant mortality rates

Year	IMR	Low CI	High CI
1985.5	27.4	25.6	29.3
1986.5	27.0	25.6	28.4
1987.5	26.6	25.5	27.8
1988.5	26.3	25.2	27.3
1989.5	25.9	24.8	26.9
1990.5	25.5	24.4	26.6
1991.5	25.1	24.0	26.2
1992.5	24.6	23.5	25.7
1993.5	24.1	23.0	25.2
1994.5	23.5	22.5	24.6
1995.5	22.9	21.9	23.9
1996.5	22.2	21.2	23.2
1997.5	21.5	20.5	22.5
1998.5	20.8	19.8	21.7
1999.5	20.0	19.0	21.0
2000.5	19.2	18.2	20.2
2001.5	18.4	17.5	19.4
2002.5	17.7	16.7	18.6
2003.5	17.0	16.0	17.9
2004.5	16.3	15.4	17.3
2005.5	15.8	14.9	16.7
2006.5	15.4	14.4	16.3
2007.5	15.1	14.1	16.1
2008.5	15.0	14.0	16.1
2009.5	15.1	14.1	16.2
2010.5	15.5	14.4	16.5
2011.5	15.9	14.8	17.0
2012.5	16.6	15.3	17.9
2013.5	17.4	15.9	19.0
2014.5	18.5	16.5	20.4
2015.5	19.7	17.1	22.2
2016.5	21.1	17.8	24.3

Our estimates have the following limitations:

i) To calculate IMR from the period after 2013, we relied on death counts reported in the NDBs. This report is a partial documentation of the overall deaths that have occurred in the country. We assumed that the proportion of under-coverage and deaths occurring in the health system remained the same so to estimate the total number of deaths. This may be not accurate; the deterioration of the registration patterns could be expected in a scenario of deep socioeconomic crisis, as in Venezuela's case. However, the implications of violating this assumption would lead to an under-estimation of the IMRs. In this sense, we warned our readers about conservative estimations.

ii) No information is available on occurred births in recent years, just information on registered births. Registered births are traditionally higher than occurred ones because of late-registration residuals from previous years are still an issue in Venezuela. Especially during the first decade of the twenty-first century when several arrangements to improve and update birth registration were implemented. We assumed the proportional difference occurred/registered held the same pattern as the previous years. Once again, this may be not accurate, and either longer delays or changes in the registration pattern could be happening during the crisis. To minimize this possible effect, we incorporated IMR with estimated ECLAC's birth counts updated using 2011 census data.

iii) There are no studies on current coverage levels of infant mortality data in Venezuela, nor enough information to indirectly estimate it after 2011. The only data sources in the country to evaluate coverage of registered data are DHS survey: ENDEVE (2010-2011), which has never been publicly available and survey ENCOVI-2016, included in this study. Considering just one survey to evaluate the coverage of the registration system after 2011 could not be sufficiently accurate, and the results obtained could be saying more about the evaluation-model's assumption than real under-coverage. This is the reason why we decided to keep the assumption of unchanged under-coverage. The limitation of this assumption is once again having conservative estimations. Coverage of Venezuela's Vital Statistic System had been improving until the first decade of the twenty-first century, as mentioned before. In a hypothetical case of continued improvement, levels already achieved (2.4%) of under-registration would not change our results significantly. Instead, in the scenario of deteriorating coverage, the main limitation of our estimations would be, once again, an under-estimation of IMR.

iv) We applied the Brass method to indirectly estimate IMR on census and survey data. This method makes assumptions about the stability of mortality and fertility patterns that may not be completely fulfilled. As such, IMR could be over-estimated. To diminish the impact of this possible over-estimation, we combined these estimations with others obtained by direct methods into the P-Splines model. Due to the problematic availability of data sources in the country, our aim is not to produce the most exact IMR estimations but the most probable ones.

v) Regarding the smoothing method (P-Splines), assumptions made by the model are the same that underlie mixed linear models. This model allows eliminating irregularities in series introduced by the combination of several data sources and methods of adjustment without losing possible changes in the pattern. One limitation in this sense is minimising out-of-range values. Because we found that the increase in IMR was indeed progressive according to all IMRs used as input to the model, the model captures smoothly the increase, giving us plausible yearly IMRs.

3. Comparing with others infant mortality estimations

We compared our estimation with international organizations IMR's estimation. For the comparison, we set as benchmark our estimations and used to determine the proportional difference with the others estimations. Three time series were chosen and they are presented in Table 5:

1) United Nation Economic Commission for Latin America and the Caribbean (ECLAC) estimates long-term mortality rates for the period 1950 to 2015 and projects its pattern until 2050. This estimation was built based on life tables implicit in the population projections, with corrections to the anomalies derived from mistakes in the recording of data.[22] ECLAC has updated all its estimation in 2016 considering last census round: 2011's Venezuelan household and population census.

2) United Nations Inter-Agency Group for estimating infant mortality (IGME) produces an annual report on trends in neonatal, infant and under-five mortality for all United Nations members combining all available sources of information in each country. Mortality rates are calculated from data on births and deaths in life tables, censuses and household surveys and when possible through vital registration systems. Estimates based on DHS surveys come directly from complete birth history or indirectly if the information is gathered in summary births histories (Brass's method).[23] All IMRs are corrected by the possible under-coverage levels and used as input data to a B-Spline model used for smooth, synthetized and predict new IMR estimations.

   IGME does not use any covariates to derive its estimates. It only applies a curve fitting method to good-quality empirical data to derive trend estimates after data quality assessment.[23] Then, harmonizes trends over time to produce up-to-date estimations. We compared our estimation with IGME updated in 2017 and those recently released in September 18th, 2018 (posterior to the initial submission of this article: May 2018). The most recent official Venezuelan data considering for the estimations is the one published by the Venezuela Ministry of Health for the year 2013, in both 2017 and 2018 IGME revisions.

   A new set of IMR produced by World Health Organization (WHO) and IGME were included in the 2018 update. IMRs were calculated by World Health Organization (WHO) and IGME, combining corrected official mortality data and population age 0 at mid-year obtained from population projections.[24] The latest data available for updating population projections in Venezuela is the 2011's household and population census. Two IMRs: for the year 2014.5 (15.01) and 2016.5 (26.69) were on this new IMR set. No information regarding the official data source of the estimation for the years after 2013 has been presented on the report. On the explanatory notes by country, the only arrangement pointed out for Venezuela's data is "a crisis adjustment in 1999.5".[25] The document also expresses there is no fixed level bias for any of the series used on the country IMR estimations.[25] With the inclusion of this new set of IMR estimations, resulting 2018 IGME's IMR for the period 2008-2012 declines to 2.8% when comparing with IGME 2017 update, and increases more than 10% annually since 2014.

3) World Health Organization (WHO) estimates annual mortality based on the information given by the countries.[26] In Venezuela's case; estimations were based on data reported by the VMH. The latest reported death counts published by VMH were in 2013. WHO adjusted both death and birth counts based on its coverage assessment of the vital statistic system and published corrected counts. Latest evaluation of Venezuela vital statistic system carried on by Pan-American Health Organization placed under-coverage in 2.4%.[4] We took corrected births and deaths to estimate IMR rates.

Table 5: Comparison with international infant mortality estimations

Year	Estimates	IGME				ECLAC		WHO	
		2017 update	% Difference	2018 update*	% Difference	IMR	% Differen ce	WHO data	% Difference
1985.5	27.4	29.7	-8	29.7	-8	31.7	-16	26.0	5
1986.5	27.0	28.8	-7	28.7	-6	30.5	-13	25.0	7
1987.5	26.6	27.8	-4	27.8	-4	29.4	-10	23.8	11
1988.5	26.3	26.7	-2	26.7	-2	28.2	-8	22.7	14
1989.5	25.9	25.7	1	25.7	1	27.1	-5	23.1	11
1990.5	25.5	24.8	3	24.7	3	25.9	-2	25.2	1
1991.5	25.1	23.9	5	23.9	5	24.8	1	24.1	4
1992.5	24.6	23.3	5	23.3	5	23.6	4	21.9	11
1993.5	24.1	22.9	5	22.9	5	22.5	7	22.1	8
1994.5	23.5	22.6	4	22.5	4	21.4	9	23.2	2
1995.5	22.9	22.1	3	22.1	3	21.0	8	23.0	-1
1996.5	22.2	21.5	3	21.5	3	20.6	7	21.5	3
1997.5	21.5	20.8	3	20.8	3	20.1	6	20.3	5
1998.5	20.8	19.9	4	20.0	4	19.7	5	19.3	7
1999.5	20.0	20.2	-1	20.2	-1	19.3	3	18.4	8
2000.5	19.2	18.5	4	18.5	4	18.9	2	17.4	10
2001.5	18.4	17.9	3	17.9	3	18.5	0	16.6	10
2002.5	17.7	17.4	2	17.4	2	18.1	-2	15.9	10
2003.5	17.0	16.9	0	16.9	0	17.7	-4	16.6	2
2004.5	16.3	16.4	0	16.4	0	17.3	-6	16.8	-3
2005.5	15.8	15.9	-1	15.9	-1	16.8	-7	15.7	1
2006.5	15.4	15.4	0	15.4	0	16.4	-7	14.9	3
2007.5	15.1	15.0	1	15.0	1	16.0	-6	14.2	6
2008.5	15.0	14.8	2	14.6	3	15.6	-4	14.1	6
2009.5	15.1	14.7	3	14.4	5	15.2	0	14.3	6
2010.5	15.5	14.7	5	14.3	7	14.8	4	14.8	4
2011.5	15.9	14.7	8	14.3	10	14.4	10	15.0	6
2012.5	16.6	14.7	11	14.6	12	14.0	16	14.8	11
2013.5	17.4	14.6	16	15.4	12	13.5	22	14.7	16
2014.5	18.5	14.5	21	16.9	8	13.1	29		
2015.5	19.7	14.3	27	19.2	2	12.8	35		
2016.5	21.1	14.0	33	22.2	-5	12.6	40		

Differences found between our estimations and those made by international organization come from the data sources used. ECLAC's estimation relies on the demographic patterns captured through information gathered on the 2011' census data. Indeed, the biggest difference among ECLAC's and our estimations (more than 10%) are seen after 2011.

In IGME case, mortality data considered come from official Vital Statistic System (VMH and VNIS) updated until 2013, same data used in this paper. Comparing with 2017 IGME estimations, main differences also started from 2011 on. Despite using the same mortality data, difference may come from non-updating the denominator, population at age 0, in a scenario that could be changing fertility pattern as well as mortality due to the crisis. The differential is kept on the 2018 IGME estimation for the years 2011 to 2014, when our estimation are higher than both IGME updates. Another difference with IGME estimations may come from possible coverage corrections. However, in both 2017 and 2018 update versions IGME estimations are lower than those propose in this paper.

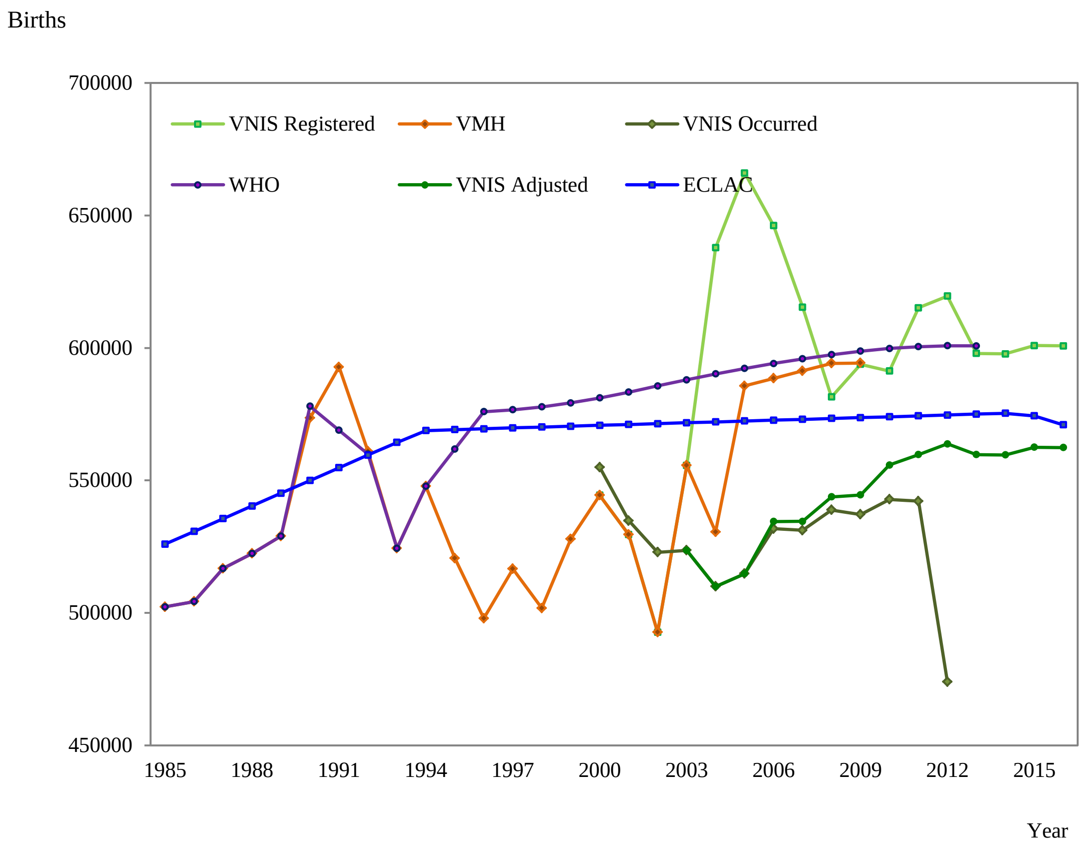
The inclusion of the IMR 2014 and 2016 on the IGME 2018 estimations gives the appearance of a sudden crisis shock, which reversed the declining trend after the year 2013. According to our estimations, the crisis was progressive and started to manifest in the year 2010 via an increasing IMR. This date could be related to the reduction of Venezuelan health system's funding since 2007 and the ceasing of vaccination campaigns occurred in many parts of the country after 2009.

Regarding estimations using WHO published data, difference with our estimation are bigger after 2011, using the same mortality data. This corroborates the idea that change in fertility may be occurring and there has not been updated in IMR estimations.

4. Recent fertility trends

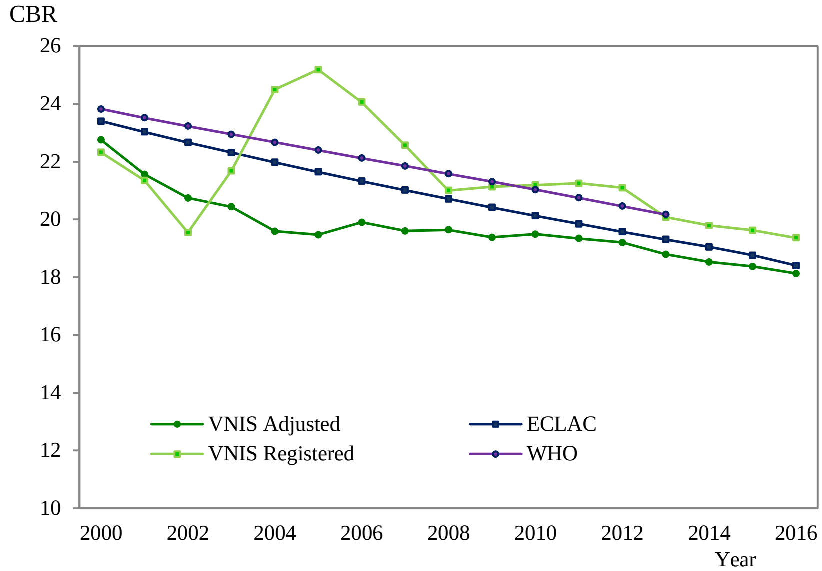
Birth counts varied significantly according to the data source Graph 1. We considered births coming from VMH, [5] WHO, [26] ECLAC [22] and VNIS. [10] Until 1996, births counts from VMH and WHO remained the same. After that point, WHO's birth estimations increased significantly, while VMH's counts were closer to those reported as registered-occurred by the VNIS. From 2004 on, VNIS registered estimations were considerably higher, this is due to the transfer of civil registry offices to public hospitals and certain number of clinics as well as active campaigns to incorporate births occurred in previous years.

Graph 1. Birth counts considering different data source, 1985-2016.

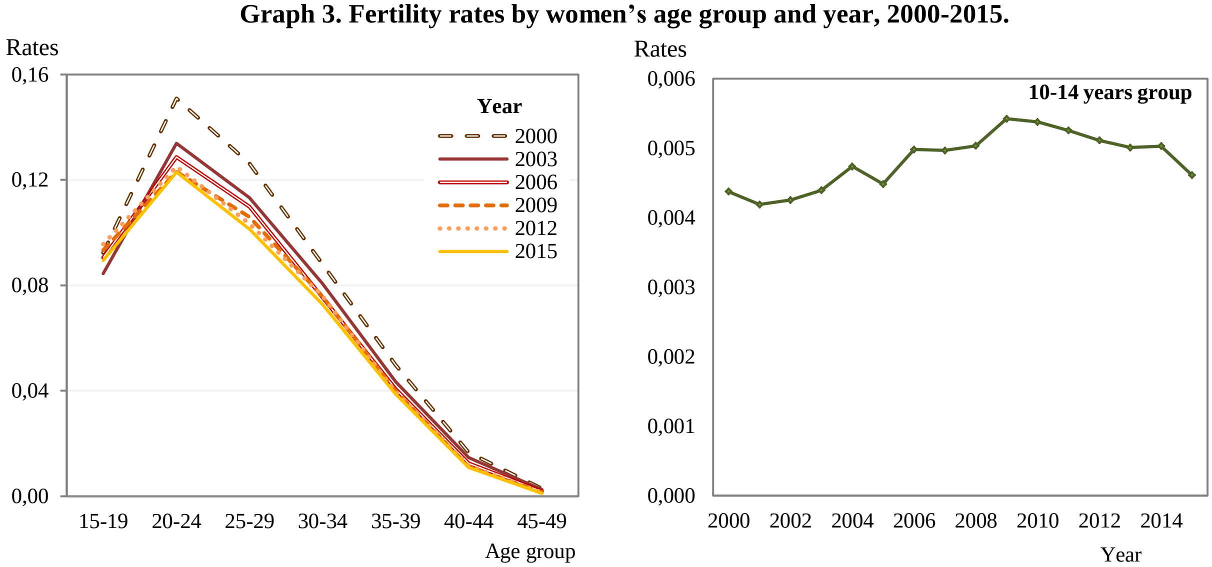


We revised recent fertility trend comparing crude birth rates (CDR) during the years 2000 to 2016 from different databases Graph 2 and the fertility structure of the years 2000 to 2015 from VNIS's birth counts[10] Graph 3. Regardless of the data source considered, there has been a decreased in CDR. Even more; fertility structure has changed through the years. All women's age groups have decreased their fertility for the whole period, except the 15 to 19 years old group. Since 2006, the 15-19 age group started to increase its fertility, being from 2009 to 2014 the period of highest increased, the same happened with the 10-14 year old group. Increasing fertility of under-19-years-old women may be increasing IMR; this is because teenage pregnancies are less like to received health care due to social prejudices, [27] late acceptances of the pregnancy, [28] low attendances to health services and inadequate health practice during the pregnancy. [29]

Graph 2. Crude birth rates considering different data source, 2000-2016.



Graph 3. Fertility rates by women's age group and year, 2000-2015.



5. Some infectious and parasitic diseases

Several epidemiological alerts have been emitted by the WHO in recent years about infectious disease outbreaks in Venezuela. Three diseases are the ones showing the biggest increase Malaria [30], Diphtheria [31] and Measles[32]. We gather all information found not just in the WHO epidemiologic alert or update but also in Morbidity yearbooks [33] and Notifiable Diseases Bulletins [8] published by the Venezuelan Ministry of Health.

We cross the information on reported and confirmed cases of these diseases in the country with reported deaths in Mortality yearbooks to establish a *lethality* rate as a ratio between reported deaths and cases per one thousand inhabitants. Likewise, we examine the incidence of the diseases through total population. *Morbidity rate* is the ratio of reported cases and total population estimated by the National Institute of Statistics based on census 2011. Morbidity rate is presented per one hundred thousand inhabitants (100,000). Data for the year 2018 is gather only for the period January to August.

Table 6: Malaria, Diphtheria and Measles reported cases and deaths

Year	MALARIA					DIPHTHERIA				MEASLE			
	Reported Cases*	Death		Lethality$	Morbidity rate+	Reported Cases*	Death	Lethality$	Morbidity rate+	Reported Cases*	Death	Lethality$	Morbidity rate+
		Total Population	under one year				Total Population				Total Population		
1995	22501	47	6	0.21	102.1	0	0	0	0.0	172	2	1.2	0.8
1996	21852	68	11	0.31	97.1	0	0	0	0.0	85	0	0.0	0.4
1997	22400	56	4	0.25	97.6	0	0	0	0.0	27	0	0.0	0.1
1998	21815	62	4	0.28	93.2	0	0	0	0.0	4	0	0.0	0.0
1999	19086	24	4	0.13	80.0	0	0	0	0.0	0	0	0.0	0.0
2000	29736	24	2	0.08	121.9	0	0	0	0.0	24	0	0.0	0.1
2001	20006	28	7	0.14	80.7	0	0	0	0.0	123	0	0.0	0.5
2002	29491	23	3	0.08	117.0	0	0	0	0.0	2391	3	0.1	9.5
2003	31719	40	2	0.13	123.8	0	0	0	0.0	0	0	0.0	0.0
2004	46655	35	1	0.08	179.2	0	0	0	0.0	0	0	0.0	0.0
2005	45049	17	1	0.04	170.4	0	0	0	0.0	0	0	0.0	0.0
2006	37062	11	0	0.03	138.0	0	0	0	0.0	95	0	0.0	0.4
2007	41749	16	0	0.04	153.1	0	0	0	0.0	23	1	4.3	0.1
2008	32037	9	1	0.03	115.7	0	0	0	0.0	0	0	0.0	0.0
2009	35828	12	0	0.03	127.5	0	0	0	0.0	0	0	0.0	0.0
2010	45155	18	2	0.04	158.3	0	0	0	0.0	nd	nd	nd	nd
2011	45824	16	1	0.03	158.3	0	0	0	0.0	286	0	0.0	1.0
2012	52803	11	0	0.02	179.8	0	0	0	0.0	391	0	0.0	1.3
2013	78643	38	2	0.05	264.0	0	0	0	0.0	178	0	0.0	0.6
2014	90708	nd	nd	nd	300.3	0	0	0	0.0	240	0	0.0	0.8
2015	136402	nd	nd	nd	445.5	0	0	0	0.0	296	0	0.0	1.0
2016	240613	nd	nd	nd	775.5	324	17	52.5	1.0	324	0	0.0	1.0
2017	319765	nd	nd	nd	1017.4	1040	103	99.0	3.3	727	0	0.0	2.3
2018 (Jan-Sep)	nd	nd	nd	nd	nd	660	40	122.7	0.7	4605	2	0.2	2.8

*nd=No data available
+Morbidity Rate= Reported cases per 100,000 inhabitants
$Lethality= Death per 1,000 reported cases

Reference

1. Pan-American Health Organization. Basic indicators. Washington: PAHO, 2014.

2. Milkkelsen et al. A global assessment of civil registration and vital statistic systems: monitoring data quality and progress. 1395-1406, s.l.: The Lancet, 2015, Vol. 386.

3. Bay, Guiomar. América Latina: diferencia relativa de las defunciones totales (por cien) implícitas en las estimaciones y proyecciones de población y las defunciones registradas y disponibles según quinquenio, 1950-2005. Santiago de Chile: Economic Commission for Latin American Countries and The Caribbean, 2015.

4. Bay, G. and Orellana, H. La calidad de las estadísticas vitales en la América Latina. Santiago de Chile: Paper presented at the expert workshop on the use of vital statistics: scope and limitations, 2007. December 2007.

5. Venezuelan Ministry of Health. Maternal and Infant Mortality, Bolivarian Republic of Venezuela, 1990-2009. Caracas: Office of Health Situation Analysis, 2012.

6. Economic Commission for Latin America and the Caribbean. Bolivarian Republic of Venezuela: Long-term population estimations and projections, 2016's revision. Santiago de Chile: ECLAC, 2017.

7. Venezuelan National Institute of Statistics. 2011 Household and population census. REDATAM micro-data. [Online] [Cited: 05 09, 2018.] http://www.redatam.ine.gob.ve/Censo2011/index.html.

8. Venezuelan Ministry of Health. Notifiable Diseases Bulletin ("Boletin epidemiologico"). Caracas: s.n., 2002-2016.

9. The collapse of the Venezuelan health system. The Lancet. 1331, s.l. : The Lancet, editorial , April 2018, Vol. 391.

10. National Institute of Statistics. Vital Statistics Query System. . Birth counts. [Online] 2000-2012. [Cited: 03 12, 2018.] http://www.ine.gov.ve/evitalesjsp/evitales.html.

11. Venezuelan National Institute of Statistics. 2001 Household and population census. REDATAM micro-data. [Online] [Cited: 03 12, 2018.] http://www.redatam.ine.gob.ve/Censo2001/index.html.

12. —. 1990 Household and Population Census. IPUMS Subset. [Online] [Cited: 05 09, 2018.] http://microdata.worldbank.org/index.php/catalog/569/data_dictionary.

13. UCAB-UCV-USB. Survey on living conditions in Venezuela ENCOVI-2016. Bengoa Fundation. [Online] [Cited: 04 10, 2018.] https://www.fundacionbengoa.org/noticias/2017/encovi-2016.asp.

14. United Nations Population Fund (UNFPA). Venezuela Population and Family Survey ENPOFAM, 1998.

15. Venezuelan National Institute of Statistics. Venezuela Demographic Survey ENDEVE, 2010.

16. United Nations. Manual of demographics techniques X. New York: United Nations, 1986.

17. DORRIGTON, R., et al., et al. Tools for Demographic Estimation. Paris: UNFPA -International Union for the Scientific Study of Population (IUSSP), 2013.

18. Verhulst A. Child mortality estimation: An assessment of summary birth history methods using microsimulation. Demo graphic Research Vol. 34, Art. 39, pp 1075–1128. Published 23 june 2016. DOI: 10.4054/DemRes.2016.34.39

19. Ahmad OB, Lopez AD, Inoue M. The decline in child mortality: a reappraisal. New York: Bulletin of the World Health Organization 78, 2000. 1175-1191.

20. Durban M, Lee D. Splines con penalizaciones (P-Splines) Teoría y aplicaciones. Universidad Publica de Navarra. Navarra, 2008.

21. Wand M. Package‘SemiPar’: Functions for semiparametric regression analysis, to complement the book: Ruppert, D., Wand, M.P. and Carroll, R.J. (2003). Semiparametric Regression. Cambridge University Press. April 2018.

22. CEPALSTAT Database. Technical notes. [Online] [Cited: 04 16, 2018.] http://interwp.cepal.org/sisgen/SisGen_MuestraFicha.asp?indicador=14&id_estudio=4.

23. UN Inter-agency Group for Child Mortality Estimation. Child Mortality. Report. [Online] [Cited: 04 20, 2018.] http://www.childmortality.org/files_v21/download/IGME%20report%202017%20child%20mortality%20final.pdf.

24. —. Explanatory Notes Child mortality trend series to 2017. [Online] [Cited: 09 24, 2018.] New York, April 2018. http://childmortality.org/files_v22/download/English_IGME_country_consultation_note.pdf

25. —. Country-specific methodological notes, New York, September 2018.

26. World Health Organization. Global Health Observatory (GHO) data: WHO Mortality database. [Online] [Cited: 09 25, 2018.] http://apps.who.int/healthinfo/statistics/mortality/whodpms/

27 Urdinola P. Determinantes socioeconómicos de la mortalidad infantil en Colombia, 1993. Revista Colombiana de Estadística, Volumen 34. Bogotá, 1993.

28 Atkin L et al. La adolescente embarazada: determinantes psicosociales en la atención prenatal. Instituto Nacional de Perinatología. México DF, 1989

29 Spinelli et al. Mortalidad Infantil. Un indicador para la gestión local. Organización Panamericana de la Salud. Buenos Aires, 2000.

30. Pan American Health Organization / World Health Organization. Epidemiological Alert: Increase of malaria in the Americas. Washington, D.C: PAHO/WHO, 30 January 2018.

31. —. Epidemiological. Update: Measles. Washington, D.C: PAHO/WHO, 9 March 2018.

32. —. Epidemiological Update: Diphtheria. 21 September 2018, Washington, D.C.: PAHO/WHO; 2018

33. Ministry of Health. Morbidity Yearbook. Caracas: Epidemiology Division, 2003-2009.