Natural Disasters and Birth Rate: Evidence from the 2010 Chilean Earthquake

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Abstract

A major natural disaster can generate changes in the affected population's behavior. As Chile is considered one of the countries with the highest seismic activity and has experienced several of the most intense earthquakes on record in the world, this work seeks to identify behavioral changes in the birth rate within an affected population related to a natural disaster in Chile. Based on evidence from the 2010 Chilean earthquake, an empirical study was carried out drawing on birth rate data and social data associated with earthquakes in Chile between 2004 and 2015. Two models were estimated. The first model is a difference-in-differences model for determining the effect of the disaster on the birth rate in the affected area in the post-disaster period. The second model is a triple-difference model that includes the trend of the data over time. The results indicate a positive relationship between the variation in the birth rate and the occurrence of the natural disaster. Studying the relationship between disaster events and fertility contributes to understanding the phenomena of social dynamics. This knowledge could improve public policy decision making for better planning in the face of a natural disaster.

Keywords

Birth rates; demography; earthquake; natural disaster; social dynamics

Introduction

Natural disasters occur on all continents and generate negative consequences in certain aspects such as social welfare, health, economy and finance, reconstruction costs, electricity supply, and housing. Chile, located on the 'Ring of Fire' [a region around the rim of the Pacific Ocean with a concentration of active volcanoes and frequent earthquakes], is considered one of the most seismically active countries with high magnitude earthquakes (Hinga, 2015). On February 27, 2010, one of the largest earthquakes in human history, number two at the national level and number six worldwide, with a magnitude of 8.8 on the Richter scale, was recorded in Chile. This earthquake was felt for almost 700 kilometers from the epicenter, affected approximately 80% of the country's population, and damaged nearly 500,000 homes (Contreras & Winckler, 2013).

The Chilean earthquake of 2010 is of great interest because of its magnitude, extent of households affected, and gross economic effect. Thanks to technological advances and storage capacity, this earthquake generated an abundance of and a variety of information, including the location of houses and their distance from the epicenter.

In response to the uncertainty of natural disasters, households may have incentives to increase the number of children to face situations such as infant mortality, compensation for loss of income, property, or assets, or even survival instinct (Finlay, 2009; Nobles et al., 2015; Park et al., 1979). The decision to have children happens after the disaster, which motivates a general expectation of an increase in birth rates following natural disasters. Several studies show that it is possible to identify a correlation between natural disasters and birth rates in the post-disaster period (Cohan & Cole, 2002; Nandi et al., 2018; Rodgers et al., 2005).

This study attempts to answer the following questions: (1) Is it possible to identify a relationship between the occurrence of a natural disaster and the birth rate in an affected population? and (2) If possible, what kind of relationship exists between these two phenomena?

Literature review

Natural disasters have been the subject of studies related to the different areas they can affect and have affected. The 2010 earthquake in Chile has been studied from different perspectives, such as factors associated with loss of income, civic assets, increasing poverty, migration, price level, health expenditures, energy and environmental resources, basic services demand, financial development, and economic growth.

Sanhueza et al. (2018) studied the effects of the 2010 Chilean earthquake in relation to social welfare. Education, health, housing, income, and work were measured explicitly as part of multidimensional poverty. This study argued that the earthquake caused a significant increase in multidimensional child poverty and that the elderly population was mostly negatively affected within the health dimension.

Concerning the looting behavior after the earthquake, Grandón et al. (2014) analyzed the effects of the 2010 earthquake related to looting, robbery, and uninhabited places after the event took place. The results highlighted that the social context associated with a neoliberal economic model favors episodes of social violence expressed in this type of phenomenon.

Other studies analyzed psychological well-being factors, such as the one carried out by López (2015), who studied the relationship between financial services that soften consumption and an individual's psychological strength when a natural disaster occurs. This work used the geographic intensity produced by the Chilean earthquake and panel data set from the national socioeconomic survey (Ministerio de Desarrollo Social, 2010), which looked at factors from about four months before and four months after an earthquake.

There are even studies that focus on the effects of natural disasters on the perinatal stage of pregnancy. In the Chilean earthquake case, it is possible to find case studies in health establishments that identified changes in the results of pregnancies. Among the findings were outcomes that negatively impact the entire maternal-neonatal areas, large-for-gestational-age babies and their relation with Mothers with diabetes and their socioeconomic status (Álvarez-Aranda et al., 2020); smaller newborns, earlier delivery, differences in length, head circumference, and changes in gestational age at birth (Palmeiro-Silva et al., 2018); and increase of congenital disabilities in babies, high incidence of premature rupture of membrane even reduction in birth-rate (Oyarzo et al., 2012).

Scapini (2020) studied the relationship between the occurrence of an earthquake and the incidence of foodborne illness. The results included an increase in the total number of diseases after the earthquake in the most drastically affected areas. In particular, Scapini found a more significant correlation in cases related to salmonella and hepatitis A. They also found a positive causal relationship between the number of diseases and the damage in the houses caused by the earthquake.

In relation to energy supply, Araneda et al. (2010) studied the impact on the infrastructure for the generation, transmission, and distribution of electrical energy. Among the results found, this study identified that the central interconnected generation and transmission network resumed its partial operation after a few hours. However, despite the building’s anti-seismic standards, the earthquake caused severe damage to some network facilities. The most severe damage took place in distribution networks, and large areas were without power supply for weeks.

Finally, Scapini and Zuñiga (2020) studied the damage to housing according to Markov’s chain model, where each instance of the chain corresponds to the occurrence of an earthquake, and the states represent the conditions in which the house is found (good, fair, and bad). Among the results obtained are the probabilities of transition from one state to another, then we see the stationary probabilities of the chain (i.e., the percentage of time that the house spends in each state in the long term).

Methodology

To study the effect of a natural disaster on the birth rate, two models were estimated. The first corresponds to a difference-in-differences model to determine the disaster’s effect on the birth rate in the affected area during the post-disaster period. The second corresponds to a triple-difference model, which requires that two assumptions be met:

- The occurrence of the earthquake is an exogenous variation and is not related to any other variable. Based on the literature review, earthquakes cannot be predicted (Kagan, 1997); therefore, this hypothesis is assumed to be true for this study.
- Parallel trend condition must be met; that is, there is no difference in the slope of the data of the variable studied between the control group and the treatment group in the period prior to an exogenous shock, which will be part of the analysis of this work.

As a first stage, the earthquake's characteristics, the affected regions, and available official data were reviewed along with investigations that addressed the 2010 Chilean earthquake. According to the 2017 census, the Chilean population was 17,574,003, and, for this study, 15 regions were considered due to available data. Simultaneously, the data about migration between regions were reviewed to assess whether there could be migratory effects. However, no relevant evidence was found to include this data in the present study. A review of the dynamics of migration in Chile during this period was expounded upon in Marambio's work (2015). The population by region, and its economic characteristics were also reviewed to identify relevant aspects to consider for the model. With that, the commune variable is identified as a control variable given the differences in size and productivity in each area. As a reference, the number of inhabitants per region and its GDP per capita, purchasing power parity (PPP) for 2008-2012 ($ at current international prices) (OECD/Eurostat, 2012; World Bank, 2020b) are found in Table 1.

Table 1*:* Population and GDP per Capita, PPP *(*current international $*)* by Region Two Years Before and Two Years After the 2010 Chilean Earthquake

Regions	Population Census 2017	2008	2009	2010	2011	2012
Arica y Parinacota	226,068	$10,303	$11,246	$12,016	$13,044	$13,476
Tarapacá	330,558	$28,832	$31,572	$38,755	$36,731	$30,703
Antofagasta	607,534	$59,155	$62,892	$82,559	$78,990	$80,979
Atacama	286,168	$26,257	$27,899	$38,536	$44,205	$43,280
Coquimbo	757,586	$11,908	$12,328	$16,900	$18,794	$18,559
Valparaíso	1,815,902	$13,850	$15,388	$18,155	$19,003	$20,179
Metropolitana de Santiago	7,112,808	$17,911	$19,433	$21,987	$23,522	$26,130
Libertador General Bernardo O'Higgins	1,395,164	$10,456	$11,601	$13,926	$14,604	$14,656
Maule	1,044,950	$10,610	$10,963	$11,617	$12,678	$13,593
Biobío	1,556,805	$15,696	$16,628	$17,882	$20,010	$20,676
La Araucanía	957,224	$8,131	$8,566	$10,086	$10,690	$11,114
Los Ríos	384,837	$10,364	$11,019	$13,084	$13,609	$14,320
Los Lagos	828,708	$10,103	$11,112	$12,173	$13,553	$13,824
Aysén del General Carlos Ibáñez del Campo	103,158	$14,918	$17,272	$19,781	$21,129	$20,436
Magallanes y de la Antártica Chilena	166,533	$20,462	$22,014	$24,806	$26,039	$27,609
Total	17,574,003	$16,620	$17,941	$21,010	$22,179	$23,471
PPP conversion factor, GDP (LCU per international $) - Chile		340.40	354.33	359.84	348.02	347.23

Note: Author's explanation based on Census 2017 (INE, 2020), Gross domestic product by region, current prices, spliced series, reference 2013 (billions of pesos) available in Central Bank (Banco

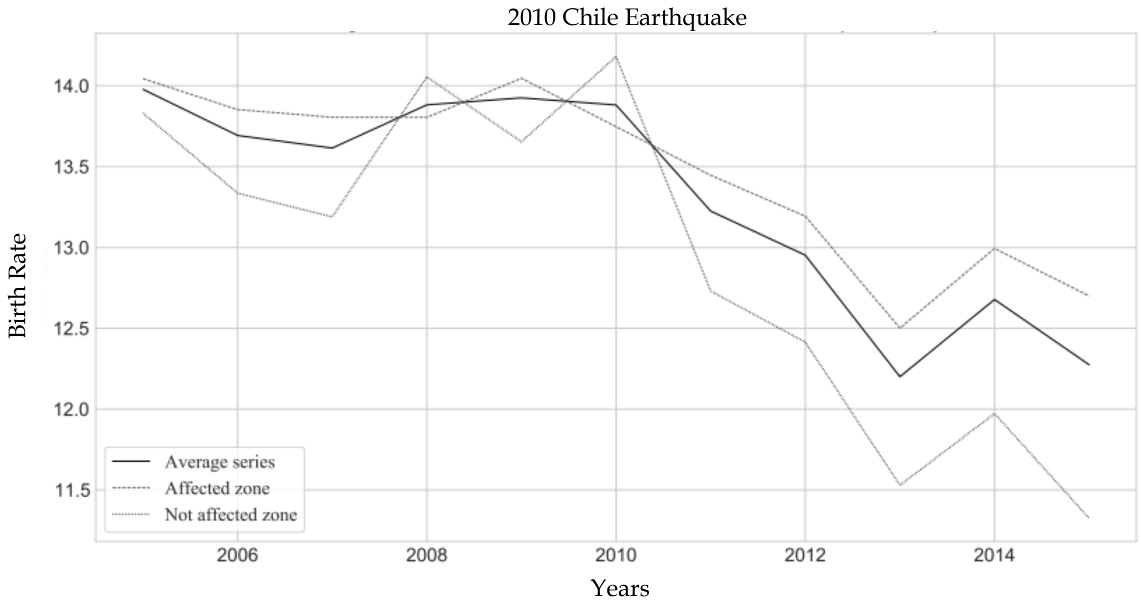
Central de Chile, 2020) and World Bank PPP conversion Factor (World Bank, 2020b) calculated as: $PPP\ GPD\ \frac{Regional\ GDP\ x\ Annual\ PPP\ Conversion\ Factor}{Region\ Inhabitants}$

Data

The data available from the Statistics Department of the Ministry of Health of Chile (known as DEIS) corresponding to the birth rate between 2002 and 2016, both years inclusive, were used to carry out the analysis. In Chile, the birth data is registered in each health center according to the day of birth, thereby generating a supporting document used for civil registration, which has over 99% completeness each year (World Bank, 2020a). Additionally, the DEIS makes periodic corrections if necessary, publishing records without mismatch between birth and civil registration dates.

The data set contains 5,182 registrations from 15 regions and 346 communes. Chile's birth rate is defined as the number of corrected live births per thousand inhabitants in a year (DEIS, 2020).

Figure 1*: Average Birth Rate Series in Affected Versus Unaffected Zones (2004-2015)*



Panel data selected from this dataset were 4,152 registrations, which correspond to the period between 2004 and 2015. This panel data shows an average of 13.85 births per thousand inhabitants between 2004 and 2009, and 12.87 births per thousand inhabitants between 2010 and 2015. The seismic intensity in each region, the mean distance from the epicenter, the birth rate, and the identification of the affected regions are presented in Table 2.

Table 2: General Data Description

Region	Average Distance from epicenter	Modified Mercalli intensity scale*	Affected	Birth-rate	
				Pre	Post
Arica y Parinacota	1,979.8	-	No	7.35	10.83
Tarapacá	1,801.2	-	No	12.98	12.65
Antofagasta	1,485.6	II	No	13.87	6.63
Atacama	937.0	IV	No	17.31	16.25
Coquimbo	604.5	VI	No	14.71	13.94
Valparaíso	462.6	VIII	Yes	13.18	13.12
Metropolitana de Santiago	324.5	VIII	Yes	15.6	11.47
Libertador B. O'Higgins	224.2	VIII	Yes	13.10	12.53
Maule	118.9	IX	Yes	13.26	12.28
Biobío	133.9	IX	Yes	13.56	12.7
La Araucanía	304.3	VIII	Yes	14.35	13.12
Los Ríos	438.3	VI	No	14.10	12.37
Los Lagos	658.3	V	No	13.83	11.92
Aisén del Gral. C. Ibáñez del Campo	1,127.5	-	No	13.81	12.39
Magallanes y de La Antártica Chilena	2,131.2	-	No	10.39	14.97

With these data, three new variables were created:

- *Affected (Aff)*: Dummy variable that indicates if the commune was affected by the earthquake. Affected communes were considered to be those belonging to the regions where the modified Mercalli intensity scale (Wood & Neumann, 1931) reached severe or higher levels (See Table 1).
- *Post (Pst)*: Dummy variable that indicates if the period is before or after the seismic event.
- *Trend (Trd)*: Captures the time trend of the data during the period.

Problem structure

These analyses were organized within two design structures: a control-group interrupted time-series design, and a difference-in-differences design. The first analytical model estimates the difference-in-difference specification in Equation 1:

$$y_{it} = \beta_0 + \beta_1 Affected_i + \beta_2 Post_t + \beta_3 Affected_i \times Post_t + \epsilon \quad (1)$$

Where the dependent variable y is the birth rate, i indexes the communes, and t the years. *Affected* is a dummy variable that indicates if the region was affected by the earthquake; *Post* is a dummy variable taking the value of 1 after the earthquake; and, *Affected* × *Post* is the interaction of these two terms.

The second model includes a linear time trend, as an indicator for the previous period, and an interaction of this *Trend* variable with the *Post* variable according to Equation 2:

$$y_{it} = \beta_0 + \beta_1 Aff_i + \beta_2 Pst_t + \beta_3 Trd_t + \beta_4 Trd_t \times Pst_t + \beta_5 Aff_i \times Trd_t + \beta_6 Aff_i \times Pst_t + \beta_7 Aff_i \times Pst_t \times Trd_t + \epsilon \quad (2)$$

In particular, the coefficient β_5 represents the difference in slope between the affected and unaffected zones by the earthquake in the prior period to its occurrence. Thus, if the coefficient is not significantly different from zero, it indicates that there is no significant slope difference between the two groups before the disaster occurs. With this, it is concluded that the assumption of parallel trends that we are verifying is fulfilled. Finally, β_7 represents the difference in slope between the affected and unaffected zones in the post-earthquake period.

Results

The analysis was performed around two linear models given by Equations 1 and 2. According to Equation 1 and the variable of interest under analysis given by the interaction between *Post x Affect* variables, it is possible to visualize, after the occurrence of the earthquake in the affected areas, an increase in the birth rate, i.e., the interaction of the *Affected* and *Post* variables shows a positive relationship. However, this increase is not statistically significant (see Table 3). The inclusion of the C*ommune* variable as a control variable generates a better fit in the result of the estimated model with an $R^2 = 0.657$ versus a $R^2 = 0.014$ without the control variable. Adding the communal variable as a control variable, although the general adjustment level improves, the obtained result is maintained.

With the second model given by Equation 2, the interaction between *Trend x Affected* is not significant in the pre-treatment period, indicating that there is no difference in the slopes of the affected and unaffected areas, at which point, the results obtained show that the demanded assumption of parallel trends between the control group and the treatment group in the period prior to exogenous shock is fulfilled.

Table 3: General Difference-in-Differences Model - Equation 1

Specification	**OLS**	
Variable	**Coefficient**	**Coefficient**
Affected	0.322	-0.701
	(0.250)	(0.810)
Post	-1.209***	-1.209***
	(0.392)	(0.247)
Affected x Post	0.357	0.357
	(0.405)	(0.254)
Control (Commune)	No	Yes
R-squared:	0.014	0.657
No. Observations	4,152	4,152

Note: Robust standard errors in parentheses
*Significance levels: *** p<0.01, ** p<0.05, * p<0.1*

Continuing with the analysis, the triple-difference was disaggregated according to Table 4, generating the results 2.1, 2.2, 2.3, and 2.4 where the main result is given by the analysis of the interaction of the variables *Trend*, *Affected*, and *Post* since it shows the difference between both groups after the earthquake considering the previous trend. Therefore, it is this variable that will allow us to conclude the work.

The partial results specified in columns 2.1 and 2.2 of Table 4 indicate that the trend in both affected and unaffected regions is not statistically different from zero before an earthquake occurrence. Meanwhile, after an earthquake occurrence, the *Trend x Post* interaction shows that the data trend decreases, and this decrease is greater in the unaffected regions.

Table 4: Summary of Equation 2 - Triple-Difference Analysis and Fit

	2.1	**2.2**	**2.3**	**2.4**
Variable	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Affected	(= Yes)	(= No)	0.475 (0.486)	-0.548 (0.799)
Post	1.003** (0.450)	4.037* (2.429)	4.037* (2.428)	4.037** (1.726)
Trend	-0.0349 (0.0431)	0.00900 (0.133)	0.00900 (0.133)	0.00900 (0.0791)
Trend x Post	-0.173*** (0.0603)	-0.558** (0.265)	-0.558** (0.264)	-0.558*** (0.182)
Affected x Trend	-	-	-0.0439 (0.140)	-0.0439 (0.0840)
Affected x Post	-	-	-3.034 (2.469)	-3.034* (1.745)
Affected x Post x Trend	-	-	0.385 (0.271)	0.385** (0.186)
Control (Commune)	No	No	No	Yes
R-squared:	0.032	0.016	0.023	0.666
No. Observations	2,868	1,284	4,152	4,152

Note: Robust standard errors in parentheses
*Significance levels: *** p<0.01, ** p<0.05, * p<0.1*

Results in column 2.3 show that the coefficient of *Trend* (for unaffected areas) is not significant, indicating a zero trend in the birth rate in the period before the earthquake. The interaction between *Trend x Affected* is not significant (in the pre-treatment period), indicating no difference in the slopes of the affected and unaffected areas. Thus, the assumption of parallel trends is fulfilled.

Within the triple interaction *Post x Affected x Trend*, it is possible to see that the trend of the birth rate increases in the affected area in relation to the unaffected area in the period after the earthquake. However, the coefficient is not significantly different from zero. Column 2.4 shows the results, including a fixed effect of the commune, which generates an improvement in the results. First of all, no significant differences are trending in the pre-treatment period; however, after treatment, a significant increase in the birth rate was found in the affected area in the period after the earthquake occurred. The results indicate that the birth rate increased 0.385 points in the area affected by the earthquake compared to that unaffected area in the post-disaster period.

Finally, to validate the obtained results, a falsifying analysis was made. To carry out this test, the earthquake event was moved instrumentally into two different moments in time, before and after the event, in 2007 and 2013, respectively. The results obtained in both estimations are shown in Table 5. Columns 2.5 and 2.6 show the result of the triple-difference model for a fictitious earthquake in 2007, not adding and adding commune fixed effect, respectively. Columns 2.7 and 2.8 show the same model results for a fictional earthquake in 2013, not adding and adding commune fixed effect, respectively. After including the fictitious earthquake in these two periods, the triple interaction coefficient *Post* x *Affected* x *Trend* shows that, in the period following the occurrence of the earthquake, the birth rate trend is not statistically different from that of the unaffected zone even if the commune variable is added as a control. The results obtained gives greater validity to the findings.

Table 5: Falsifying Analysis: Summary Equation 2 - Triple-Difference Analysis and Fit

	2.5	**2.6**	**2.7**	**2.8**
Variable	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Affected	0.316	-2.412***	0.291	-2.437***
	(0.749)	(0.786)	(0.399)	(0.561)
Post	1.519	1.519**	-1.220	-1.220
	(1.041)	(0.726)	(3.870)	(2.486)
Trend	-0.180	-0.180	-0.0928	-0.0928*
	(0.321)	(0.274)	(0.0807)	(0.0505)
Trend x Post	-0.155	-0.155	-0.00983	-0.00983
	(0.331)	(0.278)	(0.360)	(0.236)
Affected x Trend	0.0374	0.0374	0.000409	0.000409
	(0.343)	(0.288)	(0.0842)	(0.0527)
Affected x Post	-1.056	-1.056	-1.392	-1.392
	(1.090)	(0.765)	(4.068)	(2.609)
Affected x Post x Trend	0.122	0.122	0.202	0.202
	(0.353)	(0.292)	(0.378)	(0.247)
Control (Commune)	No	Yes	No	Yes
R-squared:	0.021	0.663	0.022	0.664
No. Observations	4,152	4,152	4,152	4,152

Note: Robust standard errors in parentheses
*Significance levels: *** p<0.01, ** p<0.05, * p<0.1*

Results show consistency and identify that the occurrence of a large seismic event can generate changes in the affected population's behavior concerning the birth rate.

Conclusions

This work aims to study the relationship between an earthquake and the birth rate, taking as a reference case the 2010 Chilean earthquake. The micro-level data provided by the Ministry of Health regarding the birth rate using models of difference in difference quantify and identify relationships to perform the analysis.

As initial assumptions, families exposed to the event are expected to show changes in their historical social behavior, leading to changes in health, economic, social, and demographic outcomes. Before the earthquake, the birth-rate trend in the unaffected zone during the previous period is not significantly different from zero. There is no statistical difference between the trend with this group and the group in the affected area. After the earthquake, the birth rate shows a downward trend but different in both groups. The affected zones increased by 0.38 points compared to the areas not affected during the subsequent period. With the results obtained, the discussion about the plausible causes of this phenomenon is opened, leaving it as potential future work has given the complexity of the analysis and the lack of public information that delves into the causes of the behavior. For example, studies that have managed to identify pregnancies on a case-by-case basis have been carried out with samples after agreements on the use of data available within health institutions, which is an important limitation to exploring variables and improving obtained results.

In terms of factors or causes that explain the result, it was identified that economic measures or the expectations of the economic situation of the country could generate a greater willingness to have children. However, there is no evidence on the economic side to indicate that government aid generated any incentive to have children in the face of better expectations. In addition, for this case, the evidence shows that support has been insufficient. At first glance, economic measures or better expectations would not explain the result. Even independent of natural disasters, the country has demonstrated increases in inequality, family debt, and social unrest in a generalized way (BBC, 2019; Cociña, 2017). In turn, it is important to consider that the destruction of homes constitutes a factor of socio-spatial reorganization that affects the most deprived socioeconomic sectors (Micheletti & Troncoso, 2016; Vargas Espejo, 2014). However, there was not a significant movement between regions during the post-earthquake period. Interregional migration in 2009 was 16.4%, and in 2015 it reached 17.5% (Marambio, 2015).

There is another group of studies that have found evidence of increases in the birth rate due to the need to have children again in the face of deaths or population decline caused by the natural disaster (Finlay, 2016; Nobles, 2015), which would not apply to the Chilean case given the low mortality. Thus far, according to the reviewed literature, it would remain as work to be developed to identify factors that explain the behavior change, such as the psychological effects, affective issues, post-traumatic stress, unemployment, availability of contraceptive methods, access to health facilities, change of habits, among others. Given the scope of this work, it is identified as future work of great importance to understand the factors that explain this phenomenon.

The method used with this study shows that it is appropriate to study changes in the population's behavior in the face of natural events of great magnitude that affect human settlements.

A related theory suggested that births would increase after a large seismic event; hence results obtained were consistent with most international experience where a life-threatening event encourages people to change their social behavior that altered their life decisions within their close relationships. The results obtained in this work can be useful for those responsible for the country's economic and social policies.

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