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The Changing Impact of Family Size on Adolescents' Schooling: Assessing the Exogenous Variation in Fertility Using Twins in Brazil

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Abstract Researchers have long been interested in the influence of family size on children's educational outcomes. Simply put, theories have suggested that resources are diluted within families that have more children. Although the empirical literature on developed countries has generally confirmed the theoretical prediction that family size is negatively related to children's education, studies focusing on developing societies have reported heterogeneity in this association. Recent studies addressing the endogeneity between family size and children's education have also cast doubt on the homogeneity of the negative role of family size on children's education. The goal of this study is to examine the causal effect of family size on children's education in Brazil over a 30-year period marked by important social and demographic change, and across extremely different regions within the country. We implement a twin birth instrumental variable approach to the nationally representative 1977–2009 PNAD data. Our results suggest an effect of family size on education that is not uniform throughout a period of significant social, economic, and demographic change. Rather, the causal effect of family size on adolescents' schooling resembles a gradient that ranges from positive to no effect, trending to negative.

Keywords Educational inequality · Family size · Demographic transition · Latin America · Brazil

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Introduction

Researchers have long been interested in whether and why family size[1] influences a wide range of children's educational outcomes. Simply put, it has been theorized that resources are diluted within families that have more children. Thus, the larger the family, the fewer the resources available per child, implying worse educational outcomes for each child (Blake 1981).[2] Although the empirical literature on developed countries has generally confirmed the theoretical prediction that family size is negatively related to children's educational outcomes (Blake 1981; Hauser and Sewell 1985; Powell and Steelman 1993; for excellent reviews, see Kelley 1996; Lloyd 1994; Powell et al. 2004; Steelman et al. 2002), studies focusing on less-developed societies have reported heterogeneity in the association between family size and children's education (Anh et al. 1998; Knodel et al. 1990; Knodel and Wongsith 1991; Lu and Treiman 2008; Lu 2009; Maralani 2008; Parish and Willis 1993; Patrinos and Psacharopoulos 1997; Powell et al. 2004; Pong 1997; Post 2002; Post and Pong 1998; Psacharopoulos and Arriagada 1989; Shavit and Pierce 1991), potentially reflecting the different demographic, economic, and social conditions parents face when deciding family size and the amount to invest in each child's education. A key problem for research in both developing and developed contexts is that parents who highly value children's education may decide to have fewer children in the first place (Axinn 1993; Caldwell et al. 1985), which could explain the association found in past studies. While long recognizing that parental predisposition shapes family size and children's schooling simultaneously, only recently have researchers begun to examine whether this association reflects a truly causal effect of family size on children's education.

A new wave of research centers on the use of instrumental variables to handle the endogeneity between family size and children's education.[3] This literature has examined children's education using the arguably exogenous variation in family size induced by twins (Angrist et al. 2010; Black et al. 2005, 2010; Cáceres-Delpiano 2006; Li et al. 2008; Rosenzweig and Wolpin 1980, 2000) and by sibling sex composition (Angrist et al. 2010; Black et al. 2010; Conley and Glauber 2006). The use of twins as instrumental variable is based on the idea that the birth of twins is out of parents' control and results in an unexpected increase in family size of two rather than one. Although with its own set of limitations that will be discussed herein, the use of twins as an instrumental variable arguably isolates the causal effect of family size on children's educational outcomes. When fertility and birth order are modeled jointly using twin models, the negative association between family size and

[1] We use the terms *family size*, *sibship size*, and *number of siblings* synonymously.

[2] Economic theory also posits a negative association while contending that parents invest in their children based on assessments of children's differential ability to contribute to the wealth of the entire family, therefore generating inequities within siblings (Becker 1981). Confluence theory predicts a negative effect of family size on children's education, suggesting that the mechanism lowering per-child education in larger families is the family's average intellectual environment (Zajonc and Markus 1975).

[3] Guo and VanWey (1999) were the first to use sibling fixed-effect models to handle the endogeneity resulting from parents with lower cognitive abilities having larger families. They found that the effects of family size on education disappear. Although this approach focuses on the bias from parents' preferences given their education, it does not handle the endogeneity resulting from parents adjusting their fertility in response to desired children's education.

children's educational attainment previously found has disappeared in Norway (Black et al. 2005) and in Israel (Angrist et al. 2010). A negative effect of sibship size was found for the IQ of younger cohorts of Norwegians (Black et al. 2010) and the schooling of Chinese children (Li et al. 2008).

This article draws on research suggesting historical variation in the association between family size and children's education and on the recent stream of studies using instrumental variable approaches to account for the fact that parental predisposition to educate their children also shapes family size, with the goal of assessing the causal effect of family size on children's education in Brazil over a 30-year period and across regions. While we base our work on these two research streams, we also extend previous analysis by examining heterogeneous effects of family size on adolescents' schooling over a period marked by important social and demographic change, and across extremely different regions within the same country.

Brazil offers an ideal setting for examining the variability in the causal link between family size and children's schooling. Brazil has been undergoing important changes in several areas of social life that likely have changed the context within which parents make decisions about family size and their children's schooling. Brazil's total fertility rate (TFR) fell from 6.15 births per woman in the 1960s to below replacement levels in 2006 (Ministério da Saúde 2008). At the same time, Brazil is a large country with stark social, economic, and demographic differences between its regions, more prominently between the Northeast and North versus the South and Southeast regions. The disparities between these regions are large in several aspects of social life but, particular to this research, are staggering in terms of access to education and economic conditions in the 1970s and 1980s. For example, in the North, broadly low levels of educational attainment meant that young uneducated children could make greater economic contributions to the family than was the case on the more highly educated South. On methodological grounds, Brazil offers unusually high-quality nationally representative data that encompass education from the 1970s to the late 2000s with large enough sample sizes to tackle the implications of family size for children's schooling in the northern versus the southern parts of the country.

The significance for this work is both conceptual and methodological. First, it assesses the causal link between family size and children's schooling in a developing country using twin data. Past studies have examined the association between family size and children's education, but most research in developing countries has not accounted for the potential endogeneity of family size to parents' educational plans. Second, our study covers very different social realities within the same country by exploring both historical and regional variation. Although research has suggested variation in the association between family size and children's education[4] depending on whether alternative sources of support come from the extended family (Lloyd and Blanc 1996; Shavit and Pierce 1991), from siblings (Parish and Willis 1993; Post and Pong 1998), or from state policies (Lu and Treiman 2008; Post and Pong 1998), these studies have not handled the endogeneity between family size and children's education. We are among the first to draw on twins data from a developing country to examine the causal effect of family size on children's education over three decades

[4] For excellent reviews, see Buchman and Hannum (2001) and Powell et al. (2004).

marked by substantial social and demographic change and in very different regions within the same country.

Educational Expansion and Fertility Decline Over Time and Across Regions

In the last few decades, Brazil has been undergoing important social, economic, and demographic changes. Most of Brazil's processes of industrialization, educational expansion, and fertility decline took place in the period we examine. Industrialization, agricultural modernization, and urbanization were concentrated in the South and Southeast regions (Diniz 2002). Such processes followed more than a decade later in the northern areas, causing large differences across Brazil's regions (Diniz 2002). These large regional gaps in development are accompanied by important differences in the trajectories of educational expansion and fertility decline between the poorer northern versus the more-developed southern regions. Regional differences in education and fertility levels still remain, but they are considerably smaller now than they were in the 1970s and 1980s, as we will discuss.

For most of the last century, Brazil was characterized by persistent low levels of schooling, low educational coverage, high levels of grade repetition, and problems of school access (Birdsall and Sabot 1996; Gomes-Neto and Hanushek 1994). The Brazilian educational context has improved enormously, particularly in the last decade, resulting in at least two important features: higher levels of school access and educational attainment, and smaller regional gaps. For example, Table 1 shows that only 65.49 % of children ages 7 to 15 were enrolled in school in 1970, but this proportion reached 94.96 % in 2007. Favorable demographic conditions resulting from the smaller cohorts of school-age children (Lam and Marteleto 2008) and recently implemented educational policies starting in 1995 have contributed to improvements in the levels of schooling of the late 1990s and 2000s (Veloso 2009).

Concomitant to the spread of formal education, we also see a process of declining educational gaps between the poorer North and Northeast versus the wealthier South and Southeast. Table 1 shows that 74.24 % of children ages 7 to 15 in the South and Southeast were enrolled in school in 1970; this is true for only 51.38 % of their counterparts in the North and Northeast. By 2007, a similar proportion of children were enrolled in school in both parts of the country—93.96 % in the northern versus 96.01 % in the southern regions. Although the regional gap in school enrollment had closed by 2007, important gaps in the quality of the education offered still remain. Formal education was a limited practice in Brazil until the mid- to late 1990s—with the degrees of exposure to education ranging from severely limited in the northern regions to limited in the southern regions—but the educational system has clearly expanded and incorporated the populations of all areas of the country, at least in terms of access to primary schooling (Veloso 2009).

In addition to the substantial improvements in exposure to formal education of the last years described above, Brazil has undergone a process of fertility decline during the period examined in this study. The TFR fell from 6.15 in 1960 to 5.38 in 1970, reaching 2.45 by 2000 (United Nations Population Division 2010) and below replacement levels by 2006 (Ministério da Saúde 2008). The process of fertility decline in Brazil also has large regional variations, having started later in the North and

Table 1 Percentage of adults according to years of schooling and of children and adolescents enrolled in school by year and region: Brazil, 1970, 1991, and 2007

	1970			1991			2007		
Years of Schooling	North and Northeast	South and Southeast	Brazil	North and Northeast	South and Southeast	Brazil	North and Northeast	South and Southeast	Brazil
Adults (ages 30+)									
No schooling	64.10	34.67	44.55	43.94	17.76	26.25	26.24	9.77	15.26
Some primary (1–8 years)	33.42	58.69	50.24	43.23	61.86	55.72	46.69	52.73	50.65
Some secondary (9–11 years)	1.65	4.06	3.22	9.14	11.55	10.84	19.39	22.87	21.68
Some university (at least 12 years)	0.80	2.34	1.82	3.87	8.79	7.22	7.68	14.64	12.41
N	484,789	980,574	1,538,400	991,519	1,946,159	3,131,481	77,860	90,106	188,140
Children and Adolescents									
School enrollment (ages 7–18)	47.55	65.54	58.73	61.03	74.63	68.99	88.18	89.17	88.65
N	521,222	875,904	1,480,301	978,724	1,220,455	2,357,992	44,686	35,584	89,853
School enrollment (ages 7–15)	51.38	74.24	65.49	65.41	83.39	75.86	93.96	96.01	94.96
N	405,983	675,311	1,146,055	766,095	942,501	1,830,880	33,988	26,791	67,918

Source: Brazilian census data from the Integrated Public Use Microdata Series—International (IPUMS-I) for years 1970 and 1991 (Minnesota Population Center 2010) and PNAD (National Household Sample Survey) for 2007.

Northeast than in the South and Southeast (Martine 1996; Potter et al. 2010). The early transitions typical of the southern regions were much slower than the later transitions of the northern regions, suggesting that regional differences in fertility reduced greatly over the course of the transition (Potter et al. 2010). Fertility decline in Brazil has been attributed to several factors: ideational change accompanied by material change (Potter et al. 2002); increasing use of contraception, including female sterilization (Martine 1996); and increased schooling (Lam and Duryea 1999). Although identifying one reason for fertility decline is difficult, it is safe to say that Brazil's demographic regime is now typical of a late-industrializing country, with a TFR of 1.80 in 2006 (Ministério da Saúde 2008).

The speed of Brazil's fertility decline is comparable with other large developing countries that have implemented aggressive family planning programs, except that Brazil's fertility decline took place in the absence of governmental family planning programs (Martine 1996), which suggests a strong and rapid shift from a regime where individuals lacked fertility control to one marked by fertility control. Contraceptive practice throughout the fertility transition centered on female sterilization and use of the pill (Potter 1999). The proportion of married women of reproductive ages using a contraceptive method was 66.2 % in 1986 and 76.7 % in 1996, reaching 80.6 % in 2006 (Ministério da Saúde 2008). Although prevalence has increased rapidly over time, the range of contraception methods used has remained limited, still centering on female sterilization and the pill.

Contraceptive use and the desire to limit family size have been reported by a large percentage of the population as early as in 1986. In 1986, 65.5 % of married women ages 15–49 reported the desire to limit childbearing, and this percentage reached 74.4 % in 1996 and 69.7 % in 2006 (Ministério da Saúde 2008). The high percentages of women wishing to limit family size are consistent with the idea that Brazilians were directly addressing childbearing.[5]

The Changing Implications of Family Size for Children's Education

The combination of rapid social and economic development, urbanization, educational expansion, and declining fertility has altered the composition and allocation of family resources, with direct implications for the role of family size on children's education. According to the dilution of resources framework, parental resources constitute the main mechanism connecting family size and children's education: parents in larger families provide fewer resources per child, resulting in lower educational levels (Blake 1981). This framework assumes a composition and allocation of family resources in which the net flow of resources is from parents to children rather than from children to parents or even among siblings. The framework also assumes a negligible role of support from extended kin networks to family resources. These assumptions may be valid in industrialized and low-fertility contexts, but the composition and allocation of family resources may entail alternative flows of

[5] While researchers cannot assert that couples have *complete* control over their childbearing, the use of contraception and reports on desired family sizes provide an idea of the extent to which limiting family size is in couples' agenda.

support coming from the extended family, siblings, or the state, suggesting differences on the implications of family size for children's education (Buchman and Hannum 2001; Powell et al. 2004). Indeed, Mueller has argued that in rural and less-developed societies with wide opportunities for unskilled child labor—where educated children transfer some of their earnings to parents, and kinship ties and obligations are strong—family size and children's education should be positively associated (1984). A negative relation is more likely to occur in urban areas and at later rather than earlier stages of development (Mueller 1984). Brazil's remarkable social, economic, and demographic differences across regions and over the past few decades ensure changing composition and allocation of family resources, suggesting important changes in the effect of family size on children's education.

In most Western societies, family resources include parental resources only; however, resources from relatives may play an important role in children's education. Extended family systems common to Brazil—particularly in the 1970s and 1980s—can buffer the smaller per-child parental resources in larger families, as reported in Kenya (Buchman 2000). Support from kin networks can even reverse the potentially negative role of family size, leading to advantages for certain children (Lloyd and Blanc 1996; Shavit and Pierce 1991). This is particularly likely in the early periods that we investigate and in the Northeast, where intergenerational support is higher than in the Southeast (Saad 2004).

Siblings may also be resource providers to the family by working and by taking care of younger children. In fact, Caldwell has shown that in pre-demographic transition societies, children were seen as providers of resources to the family (Caldwell 1982). When families face tighter budgets, educational opportunities are limited, and children often work in agriculture—such as in the 1970s and 1980s, particularly in the northern regions—family size may have a negligible impact on children's education because no or few children are in school. Parents had very little to invest in their children's schooling, which implies that resource dilution was not an issue. At the same time, if children contribute largely to family resources in settings where resources flow from children to parents (Caldwell 1982), we may find a positive effect of family size on children's education for all (Mueller 1984) or for some children (Lloyd and Gage-Brandon 1994; Parish and Willis 1993). If parents invest equally in all children, larger families may facilitate school attendance for all while ensuring that the work gets done (Mueller 1984). It is also possible that in large families in periods and regions with limited opportunities for education and ample opportunities for farm work, the optimal strategy could have been to have some children work while sending others to school to gain education to secure nonagricultural jobs and provide old-age support. Under these scenarios, wherein children may depend on resources from siblings to attend school, we might find that some children are not negatively affected by larger family sizes, but instead benefit from having siblings who would provide the resources necessary for their education. This is particularly likely in the Northeast, where 24.2 % of the children as young as age 10 were working in 1977. This is true of only 4.8 % of 10-year-olds in the Southeast.

By the late-2000s and in southern regions in particular, Brazilian parents were subject to a different view of childbearing and its trade-offs with education, which will plausibly yield a negative effect of family size on children's education. Formal education was no longer an unusual practice by the late 2000s. As Brazil shifted from an agricultural to an industrial society over the period we examine, fewer opportunities exist for children to work in agriculture. Children are not often seen as resource providers, and if family resources allow, parents likely nurture their children's aspirations about schooling as a result of the increasing social value placed on education. Moreover, the increasing rates of female labor force participation (Wajnman and Rios-Neto 1999) and migration patterns mean that extended family members are not as available or living as close as in the past (Ariza and Oliveira 2005). By the late 2000s, the family ties and resources necessary for children's education are likely to be more and more those provided solely by parents, with limited assistance from the extended family.

We expect historical variation in the causal effect of family size on children's education because the social, economic, and demographic changes of the past decades imply that the resources necessary for children's education are increasingly coming solely from parents, and not from siblings or the extended kin. With urbanization, development, and low fertility, children are expected to attend school and not to contribute with family resources. Resources now flow from parents to children (Caldwell 1982). Similarly, given the very different social, economic, and demographic conditions of Brazil's southern and northern regions, it is likely that the links between family size and adolescents' education also vary by region, in addition to varying over time.

The southern regions accounted for the increasing consumption and production of the 1970s, leading to an unprecedented demand for qualified labor. The fertility transition and industrialization started earlier and education expanded faster in the southern than in the northern regions. The implication of these large regional differences in the pace of development, urbanization, fertility decline, and educational expansion ensures large regional difference in the composition and distribution of family resources and on parents' ability and motivation to enroll children in school. Similar to the historical changes we discussed earlier, the differences across Brazil's southern and northern regions suggest variation in whether parents contribute solely to the family resources necessary for children's education or whether the extended kin or siblings also provide resources. While important gaps remain favoring the South and Southeast, the regional gaps in education and fertility have declined over the last decade, as we discussed earlier. We therefore expect larger regional differences on the implications of family size for adolescents' schooling in the pre-2000s period. To the best of our knowledge, no study has examined the causal effect of family size on children's education in a period encompassing most of the fertility decline in a developing country while at the same time considering the endogeneity between family size and children's schooling using a twins approach.

Data and Methods

Data

We use data from the 1977–2007 *Pesquisa Nacional por Amostra de Domicílio* (PNAD), a nationally representative household survey collected annually by the Brazilian Census Bureau (*Instituto Brasileiro de Geografia e Estatística*, IBGE).

We use an analytic sample of 12- to 18-year-old children because in Brazil, there is already extensive variation in the completed levels of education at these ages. In practical terms, because the PNAD is a household survey, the data do not allow for a count of the total number of siblings for those who do not live with their parents. Because our focus is family size, and most 12- to 18-year-olds live with at least one parent in Brazil (86.6 % for the 1977–2007 period), the use of this sample permits analyses accounting for family size. To accurately include family size in the models, we restrict the sample to children of the head of the family. When we tested for differences in the samples of children and nonchildren of the head of the family, we did not find significant differences between the two groups. Another issue with using household data to examine total number of siblings at the family level also found in previous research is that we may be missing children living outside the household (Cáceres-Delpiano 2006; Conley and Glauber 2006; Li et al. 2008). We restrict our analyses to children of mothers younger than age 40 to ensure that this is a young sample of mothers who are not likely to have older children outside the household. We also conducted consistency checks between our count measure of family size and a measure of mothers' number of living children available in a few years of the PNAD data. We find concordance between these two measures in 92 % of the cases in the 2007 data.

Our measure of children's education consists of adolescents' completed years of education at the time of the survey. While inequalities in education at early ages are strong predictors of inequalities in education in adulthood and of persistence of social stratification (Entwisle et al. 2005), a limitation with examining adolescent education is that many of them will attain more years of education as they age. A portion of the adolescents in our sample will attain higher levels of education, but extensive research has shown that the increasing mean schooling in Brazil is a result of those at the top of the educational distribution gaining more education while those at the bottom gain fewer additional years of education, since education is highly associated with social origin in Brazil[6] (Barros and Lam 1996; Lam and Duryea 1999).

Our results do not change qualitatively when we run our models with analytical samples of children and adolescents ages 7–18, 12–18, and 15–18 (available from authors). In fact, the coefficients become larger in magnitude with analytical samples of older adolescents because the variation in completed years of education increases from ages 7 to 15. At the same time, the coefficients are not estimated with the same precision in smaller samples. Age 15—the mean of the 12–18 sample—is the upper-limit age for mandatory schooling in Brazil. For these reasons, we opted to show our results for the sample of 12- to 18-year-old adolescents.

We identify twins as children living in the same household who share the same *month* and *year* of birth. Our final analytical samples for the pooled data from 1977 to 2007 in all regions of Brazil have 227,601 first-born adolescents in families of two or more children and 269,405 first- and second-born adolescents in families of three or more children. Table 2 reports the means and standard deviations of the variables

[6] Because of the inexistence of panel data on education in Brazil to follow the same sample as it ages, we follow a nationally representative cohort at ages 10, 15, 20, 25, and 30 using the PNAD data (available from authors upon request). The repeated cross sections allow for examining the educational distribution of a cohort as it ages. We find that while the distribution of education as a cohort ages yields higher means of completed schooling, it also produces larger standard deviations.

Table 2 Summary statistics of adolescents ages 12–18: Brazil, 1977 to 2007

Variable	Brazil				North and Northeast				South and Southeast			
	First-born in Families 2+		First- and Second-born in Families 3+		First-born in Families 2+		First- and Second-born in Families 3+		First-born in Families 2+		First- and Second-born in Families 3+	
Education	5.10	(2.61)	4.58	(2.58)	4.39	(2.74)	3.92	(2.66)	5.59	(2.40)	5.10	(2.38)
Age	14.63	(1.93)	14.56	(1.90)	14.63	(1.92)	14.54	(1.90)	14.63	(1.93)	14.58	(1.90)
Female	0.47	(0.50)	0.47	(0.50)	0.47	(0.50)	0.47	(0.50)	0.47	(0.50)	0.48	(0.50)
Mother's Education	5.03	(3.97)	4.16	(3.64)	4.58	(4.09)	3.81	(3.73)	5.27	(3.79)	4.35	(3.45)
Mother's Age	35.04	(3.45)	35.42	(3.36)	34.83	(3.59)	35.27	(3.47)	35.28	(3.32)	35.62	(3.24)
Father's Education	4.99	(4.20)	4.17	(3.91)	4.21	(4.21)	3.51	(3.86)	5.49	(4.05)	4.62	(3.78)
Father's Age	40.18	(7.07)	40.94	(7.22)	40.23	(7.12)	41.03	(7.03)	40.14	(7.19)	40.83	(7.59)
Per Capita Family Income[a]	556.85	(1,439.34)	370.10	(1,127.17)	483.58	(1,244.33)	340.86	(997.72)	578.81	(1,456.43)	380.67	(1,164.87)
Number of Siblings	2.59	(1.72)	3.47	(1.71)	3.00	(1.94)	3.85	(1.89)	2.31	(1.49)	3.19	(1.49)
Twins in the Family	0.018	(0.13)	0.024	(0.15)	0.019	(0.14)	0.023	(0.15)	0.018	(0.13)	0.025	(0.16)
Twins at Second Birth	0.006	(0.08)	0.005	(0.07)	0.005	(0.07)	0.004	(0.07)	0.007	(0.08)	0.006	(0.08)
Twins at Third Birth	0.005	(0.07)	0.007	(0.09)	0.005	(0.07)	0.006	(0.08)	0.005	(0.07)	0.008	(0.09)
Urban	0.78	(0.41)	0.75	(0.43)	0.73	(0.44)	0.69	(0.46)	0.82	(0.39)	0.78	(0.41)
North	0.09	(0.29)	0.10	(0.30)	—		—		—		—	
Northwest	0.28	(0.45)	0.31	(0.46)	—		—		—		—	
South	0.17	(0.38)	0.16	(0.36)	—		—		—		—	
Southwest	0.32	(0.47)	0.30	(0.46)	—		—		—		—	
Center-West	0.13	(0.33)	0.13	(0.33)	—		—		—		—	
N	227,601		269,405		86,111		111,258		112,467		123,728	

Note: Standard deviations are in parentheses.

Sources: 1977–2007 PNAD data. IBGE (National Household Sample Survey).

[a] In 2001 *Reais*.

used in the models for each analytical sample (Brazil, North and Northeast, and South and Southeast), and Table 3 shows the mean years of education by each of our covariates.

According to Table 2, the mean years of completed schooling of the 12- to 18-year-old adolescents in the North and Northeast is 4.39 (sample of first-born in families with two or more children). In the South and Southeast, it is 5.59, compared with 5.10 for the whole country. The regional differences are also evident for family size. The average number of siblings for the adolescents in our sample is 2.59 for the whole country, and 3.00 and 2.31 for the North and Northeast, and the South and Southeast regions, respectively. These regions have somewhat different age structures, yet these statistics help illustrate their different sociodemographic conditions.

Table 3 shows that for all regions considered, adolescent schooling increases with parental education and decreases with number of siblings. Adolescents whose mothers have no formal schooling have, on average, 2.95 years of schooling; their peers whose mothers have at least some college have 6.94 years of schooling. Among families with five or more children, the mean level of education is 3.30 years; among single-child families, the mean schooling is 5.90 years.

In addition to our full analytical sample for the entire country during the 1977–2007 period, we estimate models for different subsamples to explore differences across regions. Our regional analysis is based on combined samples for the South and Southeast versus the North and Northeast. Our temporal analysis is based on moving averages of pooled data sets. For constructing most year points, we pool data sets of a specific year with data sets corresponding to seven years prior and seven years after that specific year, yielding a moving average data set. The estimate for 1997, for example, is a combination of samples for the years 1990 to 2004. For our earliest and latest years, however, no PNADs are available to yield a pooled data set in the way that we describe earlier. For those cases, we pool all data sets available. For example, the estimate for our last analytical year (2007) contains data from 2000 to 2007; and the estimate for our first analytical year (1977) contains data from 1977 to 1984.

Figure 1 presents the mean number of siblings of 12- to 18-year-old adolescents over time for the entire country and separately for the northern and southern regions based on our moving average approach explained earlier. Not surprisingly, family size has declined over the period examined. Although the large regional gap in family size of the late 1970s has been closing, it still remains at around 0.5 siblings in 2007.

Methods

We first examine the relationship between family size and completed years of schooling using ordinary least squares (OLS) regression models. Because the implementation of instrumental variable (IV) models for twins is more straightforward with ordinal variables, we opted for using completed years of education as our measure of education rather than transitions to specific levels. We

Table 3 Means of completed years of education by selected variables, adolescents ages 12–18: Brazil, 1977 to 2007

Variable	Brazil		North and Northeast		South and Southeast	
	First-born in Families 2+	First- and Second-born in Families 3+	First-born in Families 2+	First- and Second-born in Families 3+	First-born in Families 2+	First- and Second-born in Families 3+
Sex						
Male	4.88 (2.61)	4.35 (2.57)	4.10 (2.73)	3.62 (2.64)	5.42 (2.39)	4.93 (2.37)
Female	5.36 (2.58)	4.84 (2.55)	4.73 (2.71)	4.26 (2.65)	5.78 (2.40)	5.29 (2.38)
Mother's Education						
0	2.95 (2.39)	2.76 (2.29)	2.43 (2.34)	2.25 (2.23)	3.65 (2.30)	3.44 (2.18)
1–4	5.02 (2.40)	4.67 (2.36)	4.37 (2.48)	4.07 (2.42)	5.44 (2.26)	5.09 (2.23)
5–8	6.21 (2.24)	5.95 (2.25)	5.74 (2.30)	5.56 (2.30)	6.46 (2.17)	6.21 (2.17)
9–11	6.60 (2.15)	6.40 (2.18)	6.34 (2.19)	6.14 (2.22)	6.81 (2.08)	6.67 (2.12)
12+	6.94 (2.06)	6.80 (2.09)	6.84 (2.13)	6.65 (2.17)	6.97 (2.01)	6.88 (2.03)
Father's Education						
0	3.13 (2.44)	2.89 (2.33)	2.73 (2.42)	2.50 (2.32)	3.76 (2.32)	3.50 (2.20)
1–4	5.07 (2.40)	4.70 (2.36)	4.51 (2.50)	4.17 (2.44)	5.41 (2.28)	5.04 (2.23)
5–8	6.12 (2.24)	5.80 (2.27)	5.74 (2.33)	5.44 (2.34)	6.33 (2.17)	6.05 (2.20)
9–11	6.54 (2.19)	6.29 (2.22)	6.27 (2.25)	6.02 (2.27)	6.72 (2.14)	6.52 (2.17)
12+	6.88 (2.10)	6.77 (2.09)	6.80 (2.17)	6.69 (2.17)	6.90 (2.05)	6.80 (2.04)
Per Capita Family Income[a]						
1st quintile	3.41 (2.49)	3.02 (2.36)	3.12 (2.52)	2.76 (2.39)	4.01 (2.30)	3.66 (2.18)
2nd quintile	4.13 (2.47)	3.66 (2.38)	3.82 (2.59)	3.38 (2.48)	4.52 (2.29)	4.06 (2.20)
3rd quintile	4.92 (2.42)	4.40 (2.38)	4.54 (2.59)	4.04 (2.53)	5.20 (2.27)	4.69 (2.22)
4th quintile	5.77 (2.35)	5.25 (2.35)	5.33 (2.54)	4.81 (2.54)	5.97 (2.23)	5.46 (2.23)
5th quintile	6.56 (2.26)	6.22 (2.31)	6.24 (2.41)	5.87 (2.47)	6.69 (2.18)	6.37 (2.22)

Table 3 (continued)

Variable	Brazil		North and Northeast		South and Southeast	
	First-born in Families 2+	First- and Second-born in Families 3+	First-born in Families 2+	First- and Second-born in Families 3+	First-born in Families 2+	First- and Second-born in Families 3+
Number of Siblings						
1	5.90 (2.34)	—	5.41 (2.50)	—	6.15 (2.22)	—
2	5.57 (2.45)	5.46 (2.38)	5.07 (2.60)	5.00 (2.53)	5.86 (2.32)	5.73 (2.25)
3	4.84 (2.54)	4.79 (2.46)	4.28 (2.64)	4.25 (2.56)	5.27 (2.38)	5.17 (2.31)
4	4.08 (2.55)	4.07 (2.48)	3.53 (2.61)	3.54 (2.55)	4.61 (2.37)	4.53 (2.31)
5+	3.30 (2.46)	3.22 (2.41)	2.90 (2.50)	2.80 (2.43)	3.88 (2.27)	3.81 (2.23)
Twins in the Family						
No	5.11 (2.61)	4.59 (2.58)	4.59 (2.58)	4.59 (2.58)	4.59 (2.58)	4.59 (2.58)
Yes	4.60 (2.62)	4.33 (2.59)	4.33 (2.59)	4.33 (2.59)	4.33 (2.59)	4.33 (2.59)
Twins at Second Birth						
No	5.10 (2.61)	4.58 (2.58)	4.39 (2.74)	3.92 (2.66)	5.59 (2.40)	5.10 (2.38)
Yes	5.29 (2.51)	5.26 (2.52)	4.65 (2.70)	4.61 (2.71)	5.67 (2.28)	5.64 (2.30)
Twins at Third Birth						
No	5.10 (2.61)	4.58 (2.58)	4.39 (2.74)	3.92 (2.66)	5.59 (2.40)	5.10 (2.38)
Yes	4.95 (2.56)	4.79 (2.48)	4.42 (2.62)	4.21 (2.55)	5.42 (2.39)	5.25 (2.33)
Urban						
No	3.65 (2.58)	3.24 (2.43)	2.83 (2.52)	2.54 (2.38)	4.47 (2.38)	4.03 (2.24)
Yes	5.50 (2.47)	5.04 (2.46)	4.97 (2.59)	4.53 (2.55)	5.84 (2.33)	5.40 (2.33)
Region						
North	5.10 (2.52)	4.70 (2.47)	—	—	—	—
Northwest	4.16 (2.76)	3.67 (2.67)	—	—	—	—

Table 3 (continued)

Variable	Brazil		North and Northeast		South and Southeast	
	First-born in Families 2+	First- and Second-born in Families 3+	First-born in Families 2+	First- and Second-born in Families 3+	First-born in Families 2+	First- and Second-born in Families 3+
South	5.73 (2.36)	5.21 (2.34)	—	—	—	—
Southwest	5.51 (2.42)	5.04 (2.40)	—	—	—	—
Center-West	5.31 (2.52)	4.87 (2.49)	—	—	—	—
N	227,601	269,405	86,111	111,258	112,467	123,728

Note: Standard deviations are in parentheses.

Sources: 1977–2007 PNAD data. IBGE (National Household Sample Survey).

[a] In 2001 *Reais*.

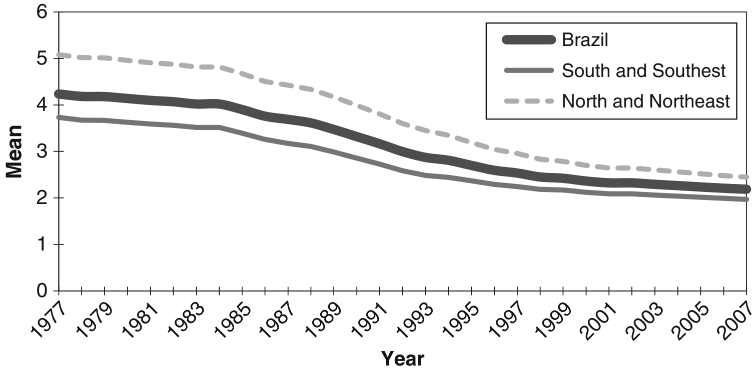

Fig. 1 Mean number of siblings, adolescents ages 12–18: Brazil and regions, 1977– 2007 (moving averages)

control for children's sex, age, mother's education, father's education, mother's age, father's age, urban or rural residence, and region of residence. We also control for log of family income (in 2001 *Reais*), which is a desirable control variable in studies of this kind that very few studies used due to recollection issues. First, we run OLS regressions of completed years of schooling on the covariates described earlier and family size. We then use a twins approach to estimate the causal effect of family size on adolescents' completed years of schooling.

The Validity and Limitations of Using Twins as an Instrumental Variable

The argument for using twins as an instrumental variable is that the birth of twins results in an increase in family size that is out of parents' control, which would purge the endogeneity between family size and children's education. The use of twins as an approach to handle endogeneity bias was first implemented by Rosenzweig and Wolpin (1980). They first used a twins ratio—the number of twin births divided by the number of pregnancies—in an attempt to eliminate the endogeneity problem. In later work, they examined first-born children separately (Rosenzweig and Wolpin 2000). Three more recent papers have proposed examining the outcomes of *n*th order children in families of $n + 1$ or more children, using the birth of twins at the *n*th + 1 order as instrumental variables (Angrist et al. 2010; Black et al. 2005, 2010). Selecting a sample of children at a birth order lower than that of the twin birth avoids selection problems that arise because families who choose to have another child after a twin birth may differ from families who choose to have another child after a singleton birth. We follow this approach to construct our instrumental variables and to implement our two-stage least squares (2SLS) models. We first restrict the sample to families with at least two children and examine the completed years of education of the first-born (twin at second birth as instrumental variable). Next, we restrict the sample to families with at least three children and examine the completed years of education of the first- and second-born children (twin at third birth as instrumental variable).

For the research questions we address, a good instrument should be correlated with family size and be correlated with completed years of schooling only through family size: that is, the occurrence of twins should be a random event. A possible threat to this assumption of randomness is a choice of new reproductive techniques, such as in vitro fertilization (IVF). About 25 % of pregnancies with IVF result in the birth of twins. The issue arises because parents who use IVF treatments—and therefore more likely to have twins—are potentially different from parents who do not use IVF. The correlation of twin births and unobserved family characteristics is, by definition, untestable. We cannot control for different tastes between parents who opt or not for a reproductive technique, but we can control for observable differences. Following past research (Black et al. 2005, 2010), we examine whether the occurrence of twins is associated with observable family characteristics. We find that the probability of having a twin birth is uncorrelated with parents' education and family income in any given year or region that we examine, as well as in the full sample.

Another potential matter with the use of twins as instrumental variable is its external validity. If the proportion of twins—and therefore of adolescents with twin siblings—had substantially increased over time[7] (because of fertility treatments, for example), then our instrument could become invalid. The proportion of first-born adolescents in families of two or more children (which had twins at second birth) for the entire country and in the 1977–2007 period is .006, as shown in Table 2. These proportions are around .0057 in the earlier years and .0062 in the later years, a very small variation given our 30-year analytical period. This shows that fertility treatments are not of significant concern in the Brazilian context, ensuring the validity of our instrument over time. It is important to note that although the proportion of 12- to 18-year-olds with twin siblings did not increase over the period of time we examine, the magnitude of the association between a twin birth and family size has increased, as we will show here in the results from the first-stage models. Families became substantially smaller during the period we examine, leading to a larger impact of twins on the smaller families of the 2000s than on the larger families of the 1970s and 1980s.

Another important limitation with using twins as instrumental variable to examine the effect of family size on children's education is that the analysis must be conducted on subsets of the population. One way that we increase the generalization of our findings beyond twin families is by examining children born prior to their twin siblings versus those who do not have twin siblings. Although we gain analytical strength when examining the completed schooling of children born prior to the birth of their second- and third-order siblings, reflecting on the implications of this selection is equally important (Moffitt 2005). In that sense, our analysis is restricted to early-born children, and differences are likely to occur on the meanings of larger

[7] Fertility treatments became accessible in Brazil in the late 1990s (Borlot and Trindade 2004). Being precise about the number of fertility clinics and procedures is impossible because no specific legislation regulates the practice. The Latin American Registry System (*Registro Latinoamericano de Reproducción Asistida*)—a surveillance system covering more than 90 % of the centers offering such technologies in Latin America—estimates that the entire region has nearly 90 clinics (Zegers-Hochschild 2002). A report from the World Health Organization estimates that 6,480 live births were produced via reproductive techniques in the region from 1991 to 1998 (Zegers-Hochschild 2002). It is estimated that Brazil shares 42.9 % of the cases, which yields 308 cases per year during this eight-year period. Based on the Demographic and Health Surveys report of 3,495,249 live births in Brazil in 1996 (Macro International 1996), we roughly estimate that 0.000088 of these births could have been produced through a fertility technology treatment, a small enough proportion not to significantly affect our analysis.

Table 4 Ordinary least squares (OLS) and two-stage least squares (2SLS) estimates of the effect of family size on adolescents' completed years of education using twins as IV, adolescents ages 12–18: Brazil, 1977 to 2007

Sample/Instrument	OLS (1)	2SLS First Stage (2)	2SLS Second Stage (3)
Non-twin First-Born Children in Families With 2+ Children			
Instrument: Twins at second birth		0.611** (0.034)	
Number of siblings	–0.248** (0.003)		0.064 (0.076)
N = 227,601			
Non-twin First- and Second-Born Children in Families With 3+ Children			
Instrument: Twins at third birth		0.773** (0.030)	
Number of siblings	–0.240** (0.003)		0.131* (0.055)
N = 269,405			

Notes: Robust standard errors, shown in parentheses, allow for correlation of errors within family. All regressions include controls for age, age squared, mother's education, father's education, mother's age, sex, urban location, and log of family income.

Sources: 1977–2007 PNAD data. IBGE (National Household Sample Survey).

*$p < .05$; **$p < .01$

family sizes for earlier-born *vis-à-vis* later-born children. We return to the implications of this limitation when we discuss our findings.

Results

Table 4 presents the OLS and 2SLS estimates of the effect of family size on children's completed years of education using a twin approach for the sample of first- and second-born children from 1977 to 2007. The results from the OLS estimates show a consistent negative and statistically significant correlation between family size and adolescents' years of schooling. For example, column 1 in Table 4 shows that one more sibling is associated with a reduction in children's schooling of approximately .248 for first-borns in families of two or more children. An additional sibling is also associated with .240 fewer years of schooling for first- and second-born adolescents in families of three or more children.

The results from the 2SLS models offer a different story. The 2SLS estimates shown in column 3 suggest that the negative and statistically significant associations between family size and schooling estimated through the OLS models disappear. The family size coefficients of the 2SLS models show a positive sign, although only statistically significantly for the sample of first- and second-born children in families of three or more children. Column 3 reports that larger family sizes induced by the unexpected birth of twins are related to higher levels of schooling by .131. The control variables have the expected signs (available from authors). In general, females have an educational advantage over males, consistent with the educational pattern of most Latin American countries. Mother's and father's education are positively related with schooling, as is family income.

Column 2 shows the first-stage estimates of the relationship between family size and each of the two twin instruments. It is worth noting that the first-stage associations between family size and a twin birth at second and third orders are statistically significant for both specifications, with *F* tests of above 45. Consistent with the range of coefficients found in previous research that used twins as IV for estimating the effect of family size on children's schooling (Angrist et al. 2010; Black et al. 2005), the coefficients representing the relationship between family size and a twin is .611 for twins at the second-order instruments and .773 for twins at the third-order instruments.

Temporal Analysis

To examine our hypothesis of changing effects of family size over a period of significant change, we estimated the same models as the ones presented in Table 4 using moving averages. We focus this analysis on the sample of first- and second-born children in families with three or more children, using twins at third birth as the IV. Although we estimated similar models using the sample of first-born children in families with two or more children, the coefficients are not statistically significant, which is why we proceed to examine first- and second-born children in families of three children or more in more detail. We believe that this is the case because the models are estimated with higher precision for the sample of first- and second-born children. The corresponding OLS and 2SLS estimates that form Fig. 2 are provided in Table S1 in Online Resource 1.

Figure 2 shows a striking trend of changing implications of family size for completed years of education over time. The coefficient representing the effect of family size on adolescents' schooling is positive and statistically significant at the .01 or .05 levels from 1977 to 1990. Not only that, the lower bounds of the 95 % confidence intervals for all estimates up to 1991 suggest that a negative value is very unlikely. With the exception of 1994, the family size estimates are statistically significant at the .10 level from 1991 to 1996, but become no longer statistically different from 0 after that.

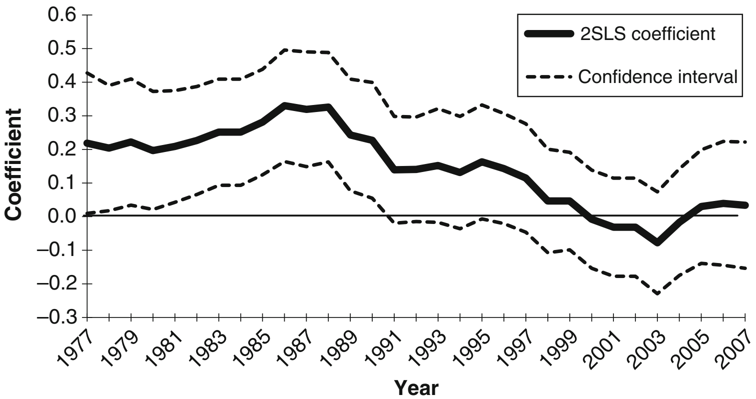

Fig. 2 Family size coefficients from 2SLS models of completed years of education: First- and second-born adolescents ages 12–18, Brazil, 1977–2007 (moving averages)

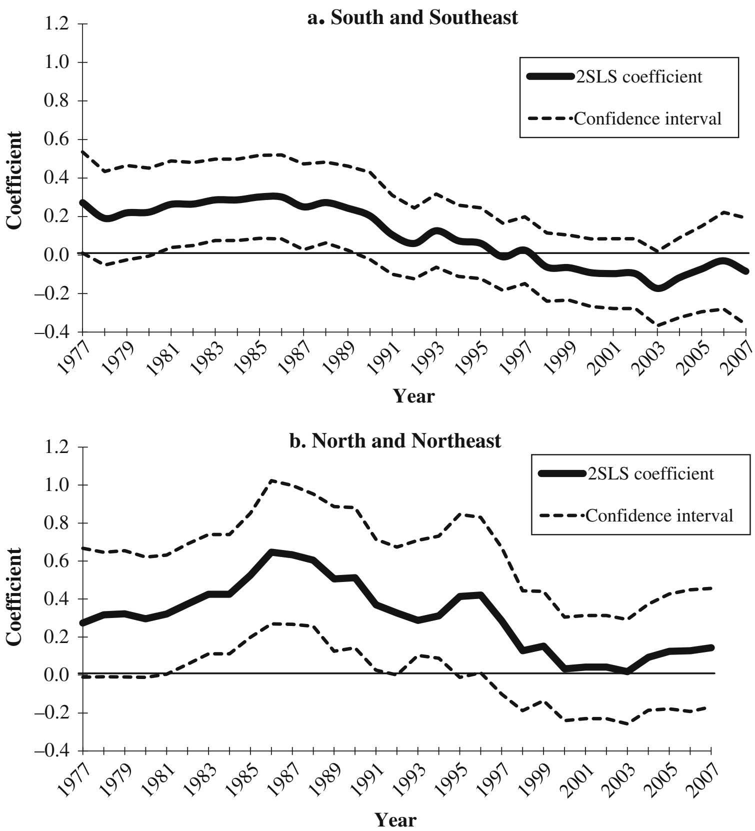

Fig. 3 Family size coefficients from 2SLS models of completed years of education: First- and second-born adolescents ages 12–18, Brazil, 1977–2007 (moving averages)

These results suggest that family size is beneficial to the schooling of first- and second-born adolescents in periods of high fertility and low educational aspirations. When child agricultural work becomes less frequent and the opportunity costs of not going to school become high, the effect of family size on children' schooling is no longer statistically different from 0. These findings are consistent with research in developed countries (Angrist et al. 2010; Black et al. 2005) in that the negative effect of family size on children's schooling disappears when estimated through 2SLS models in developed countries.

Regional Analysis

Given the different socioeconomic and demographic conditions of Brazil's regions discussed earlier, the effects of family size on children's schooling will also likely vary by region, in addition to the temporal variations reported earlier. Figure 3 shows the coefficients corresponding to family size in models with twins at third-order as instrument similar to those presented in Fig. 2, but estimated separately by region. Panel A refers to the South and Southeast, and panel B refers to the North and Northeast. Table S1 in the online supplement shows full results from the corresponding OLS and 2SLS models.

As with Fig. 2, we estimated the models using the moving average approach discussed earlier. It is worth mentioning that the first-stage estimates range from .539 to .800 in the North and Northeast and from .711 to .930 in the South and Southeast, and that all the F tests for the first-stage models are above 48. The first-stage estimates representing twins have increased over time in both regions, suggesting that the implications of a twin for family size have increased over time. This is expected and indicates that a twin increases the family sizes at higher rates in the later versus the earlier years, and in the northern versus the southern regions, reflecting the dramatic declines in family size during the 30 years that we examine.

Figure 3 highlights at least three important patterns. First, the figure suggests a trend in the effect of family size on adolescents' education that varies not only over time but also across regions marked by very different patterns of socioeconomic development and fertility levels. This reinforces our interpretation of an effect of family size that is not homogenous, but instead varying with the realities around parents' decision-making processes.

Panel a of Fig. 3 shows that the estimates representing family size are positive until 1997 in the southern regions, with the exception of 1996, when the coefficient approaches 0. However, these estimates are statistically significant at the .01 or .05 levels only in 1977 and from 1981 until 1989, as shown in Table S1 in the online supplement. The statistically significant advantage associated with having an additional sibling disappears after 1990. The coefficients even become negative after 1996. The results for the northern regions shown in panel b of Fig. 3 highlight a similar story, except that the estimates are positive for the entire series, from 1977 to 2007. The positive and statistically significant estimates last longer in the northern regions. After 1996, our results show no statistically significant effect of family size on adolescents' completed years of education even for the North/Northeast. While the 95 % confidence intervals for the point estimates in the northern regions suggest that a negative effect is unlikely until 1996, this is true for the southern regions only until 1989, showing that any possible advantage associated with larger families disappeared earlier in the southern than in the northern regions.

Figure 3 also shows that the magnitude of the advantages on adolescents' education associated with family size is larger in the northern than in the southern regions. This is particularly true throughout the 1980s and 1990s, when the educational and fertility gaps across these regions were larger. Not only that, but the positive effect disappears earlier in the southern than in the northern areas, mirroring the trend of increasing levels of school access, educational attainment, and fertility decline that took place earlier in this part of the country. By 1997, any statistically significant advantage associated with family size has disappeared in both regions.

Conclusions and Discussion

The goal of this article was to assess the causal effect of family size on adolescents' completed years of education over a period of significant social, economic, and demographic change in Brazil and across regions. Understanding the determinants of education is the first step to addressing broader inequalities in social opportunity. We considered the different social realities parents face when making their decisions by comparing periods and regions with very different levels of formal education, access to schools, socioeconomic, development, and fertility regimes. We used nationally representative data and employed OLS and 2SLS models using twins as instrumental variables. Our study is the first to use a twin approach to examine the causal link between family size and adolescents' schooling over an extensive period of time and in regions that range from lower to higher levels of development and from high to low fertility.

Our results imply an effect of family size on education that is not uniform throughout a period of significant social, economic, and demographic change. Rather, the causal effect of family size on adolescents' schooling resembles a gradient that ranges from positive to no effect, trending to negative. More precisely, the effect is positive in periods and regions in the earlier stages of socioeconomic development and with high fertility; but the effect disappears for recent periods when the opportunities for child farm work have declined, education has expanded, and fertility has declined to below-replacement levels. This is an important finding because it confirms that the causal effect of family size on children's education is neither homogenous nor rigid, but varies with the social context surrounding parents' fertility and educational decisions.

Our findings suggest that adolescents benefited from being in larger families until the mid-1990s, with the northern regions driving this pattern for a longer period of time. In explaining this finding, it is important to note that our analysis is limited to first- and second-born children because our samples—and twin analysis of this kind in general—are limited to early-born children. Although the narrow sample of first- and second-born children is a limitation of our analytic approach, we interpret that larger family sizes are beneficial to the education of early-born children because it potentially reflects two different parental strategies in periods of high fertility, sufficient opportunity for agricultural work, and low educational aspirations. If parents invest equally in all children, each child in larger families can combine work and school and still provide resources to the family unit more easily than in smaller families (Mueller 1984). On the other hand, parents' strategy may be to diversify risk by having some children work while keeping others in school to gain enough education to secure nonagricultural jobs and old-age security. This explanation is consistent with economic theory in that parents act for overall family well-being (Becker 1981), reinforcing rather than compensating for their children's differences (Behrman et al. 1994). Although our analysis does not focus on later-born children, a tendency of parents to invest in earlier-born children is possible in Brazil—at least in earlier stages of socioeconomic development—and has been documented in Asian societies (Yu and Su 2006). The returns to schooling were extremely high in Brazil in the 1970s and 1980s (Lam and Levison 1992), and parents get faster returns on their investing in earlier-born rather than later-born children as a strategy for family well-being. In fact, the so-called chain arrangement, in which the oldest child is educated at the parents' expense and is obliged to contribute to the education of younger children, has been reported in Asia and Africa (Mueller 1984). Although this explanation is also in line with the confluence model in which early-born children benefit from mentoring younger siblings (Zajonc and Markus 1975), it is in contrast with reports from developed countries where later-born children are better off because of the family stage in the life course (Steelman and Powell 1991). Attributing our findings to parents investing more on earlier-born rather than later-born children is also in contrast with evidence that early-born girls fare particularly poorly in Taiwan (Parish and Willis 1993). A fruitful direction for research extending our findings is to examine the implications of family size and birth order for additional adolescent outcomes, such as economic and household work over an extended time period, while considering the endogeneity between family size and children's well-being.

The positive effect of family size on adolescents' schooling disappears around the 1990s for the whole country, having lasted longer in the northern than in the southern regions. This suggests that the implications of family size for adolescents' education seem to be converging in the northern and southern regions. Our findings show no statistically significant effect of family size on adolescents' completed years of education thereafter, with a tendency toward a negative effect confirmed by the southern estimates. This overall finding for the past 15 years is consistent with the only recent study that has explicitly examined cohort and period differences using a twins approach. Black et al. (2010) found that the family size effect on IQ was absent for older cohorts but has become negative and statistically significant for younger cohorts of Norwegians. We argue that research in developed countries has yielded either a negative or no causal effect of family size on children's education because they are situated in times when education had expanded to at least universal levels of primary school enrollment and parents were already limiting their desired family size, therefore potentially exerting a quantity-quality effect. To be clear, we are not arguing that Brazil will resemble Norway as socioeconomic development spreads, but rather that the social, economic, and demographic contexts surrounding parents' decisions define the causal link between family size and children's education in important ways. Because our investigation of the causal connection between family size and children's education includes periods and regions with limited educational aspirations, low levels of economic development, high fertility levels, and a child-parent flow of resources, our estimates reflect a process that is very different from the one reported by most past research using twin methods. Thus, the evidence in this study is consistent with the idea that the effect of family size on adolescents' schooling is not homogenous over time or across extremely different regions within the same country: development in Brazil, whether measured by educational expansion or lower fertility levels, or whether examined for all of Brazil or separately for the North and the South, has clearly changed the causal connection between family size and education.

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