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ORIGINAL ARTICLE

Are sex-selective abortions a characteristic of every poor region? Evidence from Brazil

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Abstract
Objectives Introduction of ultrasound equipment has been associated with higher sex ratio (number of male live births divided by female live births) for some developing countries. So far, studies have solely focused in regions with a cultural preference for males, which may introduce misleading conclusions about the association between poverty and sex-selective abortions.
Methods We analyzed poor Brazilian municipalities that either (a) did not have ultrasound equipment, or (b) had the introduction of ultrasound equipment for the first time. Propensity score matching was performed, resulting in 155 pairs of comparable municipalities.
Results We found a sex ratio of 1.039 for municipalities that had the introduction of ultrasound equipment and of 1.047 for those that did not. The difference between the two groups was not statistically significant. The use of the propensity score matching approach was successful in reducing bias.
Conclusions Concerns about an association between local poverty and sex-selective abortions should not be a barrier against access to maternal technology. While sex-selective abortions are an important concern for some developing countries, they are not a specific characteristic of poverty.

Keywords Sex ratio · Sex-selective abortions · Ultrasound equipment · Brazil

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Introduction

The natural sex ratio at birth has been consistently found to be 1.03–1.07 male per female births (James 1987; Parazzini et al. 1998). For some regions, especially rural parts of Asia, much higher rates have been reported. Recent sex ratio imbalances have been particularly high for China (1.19), South Korea (1.10) and India (1.08) (World Bank 2012). In China alone, it is estimated that an annual excess of 1 million boys are born each year (Miller 2001).

The consequences of this imbalance include a diverse range of social and demographic issues. Surplus males in China have been associated with challenges in maintaining full employment (Hudson and Den Boer 2004). Lower availability of reproductive-age women has led to the emergence of a "bride market", the expansion of the number of female sex workers and the dissemination of sexually transmitted diseases (Tucker et al. 2005).

Some studies have found that, in India and China, sex-selective abortions have been increasing with ultrasound presence, but how much of the sex ratio that can be attributed to its availability is still in dispute (Ganatra 2008; Li and Zheng 2009; Zhou et al. 2012). A higher than expected sex ratio for children has been reported in India and China as early as the mid-20th century, when data first became available (Junhong 2001; Bhat and Zavier 2007). Even though it has been historically higher during the last few decades in China, the sex ratio at birth started to increase steeply by the mid-1970s, whereas, ultrasound was not available anywhere in the country (Löfstedt et al. 2004). Reliable data for the presence of ultrasound equipment in some regions has been historically nonexistent, as incentives for underreporting its usage are mutually beneficial for physicians working in private clinics and families interested in pursuing sex-selection without governmental regulation (Junhong 2001).

Along with Korea and Singapore, high sex ratios in China have been attributed to cultural factors, especially the influence of Confucianism (Das Gupta 2010), where tight intergenerational bonds are defined through the male hereditary line. Sons are also expected to provide economic support for parents, while daughters are frequently considered to "belong" to the families that they marry into (and thereafter provide care for aging parents-in-law) (Laiwan et al. 2006). There is evidence that similar cultural factors may also be influencing India's high sex ratio at birth (Das Gupta 1987).

Studies on ultrasound availability and sex ratios have focused so far in countries with a historically high proportion of male births. This can distort the conclusions, especially in the case of China where the One Child Policy may influence parents not to register female births (Wu et al. 2006).

The temporal correlation between an increase in the availability of ultrasound equipment and the sex ratio at birth has raised ethical concerns about the dissemination of this technology (Ganatra 2008; Harris and Marks 2009; Edwards and Thomson 2012), as studies have pointed out the existence of economic benefits from having a son over a daughter in very impoverished areas (Edlund and Lee 2009; Frost 2011), especially in those highly dependent on agriculture (Burgess and Zhuang 2000).

The possibility of maternal technology being used for fetal sexing is currently considered to be one of the major hindrances to its dissemination in poor regions (Harris and Marks 2009). Two recent reports by the United Nations and the World Health Organization have expressed concerns that "limitation of technology for sex selective abortion could lead to a general limitation of access to technologies", thereby "exposing women to higher risk of death and serious injury" (United Nations Population Fund 2010; World Health Organization 2011).

Brazil has been going through a consistent trajectory of growth and reduction of income inequality during the last decades, but its poor residents are still among the poorest in the world (Milanovic 2007). The absence of access to contraceptive methods and reproductive information in poorer regions of Brazil have put its residents in particular risk of unsafe abortions and its consequences (Fusco et al. 2012). In Brazil, abortions are illegal except when there is clear maternal death risk, it is a consequence of rape or, most recently (by a 2012 Supreme Court decision) in the case of anencephaly. Heated political debates have been taking place in Congress between defenders of the legalization of abortion and proponents of the criminalization of any type of abortion (Victora et al. 2011). Nevertheless, the illegal practice of abortions is considered to be currently widespread by the government, as it is estimated that more than one million illegal abortions are performed annually (Diniz 2008).

The objective of the analysis is to test the presence of sex-selective abortion in a very poor area. As far as we are concerned, there have been no studies that analyzed the association between the introduction of ultrasound equipment and sex ratios in poor areas without a cultural history of male preference. We test this by analyzing the poorest regions of Brazil, a country without a history of unbalanced sex ratios.

Methods

Brazil has a unified system of universal health care available for every resident, a basic right provided by its 1988 constitution. Every health institution in the country is required to inform availability of health professionals and physical equipment through the national health establishments records (Cadastro Nacional de Estabelecimentos de Saúde, CNES) (CNES 2012a). Employees from the CNES perform random frequent visits to test compliance. In the case of misleading or incomplete reports, health institutions face termination of funding and temporary closures (CNES 2012b).

Presence of active ultrasound equipment by municipalities was provided by the CNES from 2005 to 2010. We included in the analysis the ten poorest States (out of 26) of Brazil, as informed by the Census 2010 values for per capita income (IBGE 2012). The inclusion of only the poorest (mostly rural) regions meant that at least some of them did not have ultrasound equipment in the beginning of the period, which made the analysis possible. The average monthly income for the ten states was BR$464.2 for residents older than 10 years old, the equivalent of US$263.3 in July 31 2010 (baseline date of the Census).

A total of 1,832 municipalities were included in the first part of the analysis. For each of them, presence of active ultrasound equipment was analyzed. Two groups of municipalities were selected: the ones that had the introduction of ultrasound for the first time during the 2005–2009 period (and remained with it for at least 1 year following the introduction, making 2010 the last year analyzed), and the ones that did not have any ultrasound equipment during the period. The first group was considered "exposed" (to ultrasound equipment) the second "unexposed". We also excluded municipalities with less than 100 live births a year (calculated for 2010) to decrease the effect of random annual variation in the sex ratio. A total of 534 municipalities matched all the criteria and were included in the statistical analysis.

We included covariates to control for the effects of socioeconomic characteristics, as low income and high risk pregnancies have been associated with a naturally higher male fetal mortality (Di Renzo et al. 2007; Navara 2010;

Chiavegatto Filho and Laurenti 2012). Data for percentage of residents living in households with piped water, percentage of residents living in households with electricity, percentage of residents living in households with garbage collection, average income for residents older than 10 years old, percentage of white residents and literacy rate for residents older than 10 years old, were calculated using data from the 2010 Census (IBGE 2012). Data for percentage of teenage mothers (younger than 20 years old), percentage of mother with less than 8 years of education (the minimum required for Brazil), percentage of single (non-married) mothers, percentage of premature births (<37 weeks), percentage of low birth weight (<2,500 g), total number of births and female fertility (per 1,000 reproductive-age women, 15–49 years old), were calculated using data from the Ministry of Health for 2010 (Datasus 2012). After the selection of the variables, no further changes were made (i.e. no variables were included or excluded during the propensity score analysis). Sex ratios were presented by dividing the number of male live births by the number of female live births, e.g. if 105 boys and 100 girls were born the sex ratio is 105/100 = 1.05.

Statistical analysis

We used propensity score matching to identify and pair municipalities that could be considered as similar, conditional on exposure (defined as introduction of ultrasound equipment during the period) (Rubin 1997). The propensity score methodology allows the reduction of a large set of covariates into a single scalar summary variable, and as it does not make assessments about the prediction of individual variables, it avoids multicollinearity (Conniffe et al. 2000).

We first estimated the probability of being exposed given the covariates by calculating the propensity scores for each municipality. We then matched municipalities on a one-by-one basis using a caliper width of 0.01 (the most frequently found in the literature). The area under the ROC curve (or *c*-statistic) was 0.75, the exact midpoint between 0.5, a coin toss classification, and 1.0, perfect classification, which allowed a desirable amount of overlap between the municipalities. Of the 228 exposed municipalities, 155 had a propensity score within the caliper width of 0.01 of an unexposed municipality and were included in the analysis. This allowed the comparison of 155 pairs of exposed and unexposed municipalities with similar covariates distribution.

After identifying the pairs by the propensity score matching approach, we calculated the sex ratios for the year after the introduction of ultrasound equipment (same year for pairs of exposed and unexposed, e.g. if the exposed municipality had the introduction in 2006, the sex ratio was calculated for 2007 for both exposed and unexposed). This was followed by a paired *t* test analysis of difference.

We also conducted a sensitivity analysis for average treatment effects using Mantel–Haenszel bounds to identify hidden bias due to the effect of unobserved variables on exposure and the outcome variable (Becker and Caliendo 2007). We found the final result to be very robust, being statistically insensitive to a bias that would increase up to six times ($\Gamma = 6$) the odds of exposure to ultrasound equipment.

Results

Table 1 shows the results for the covariates before matching by the propensity score approach for the 534 municipalities first selected for the statistical analysis. Before the matching process, exposed municipalities had statistically higher ($p < 0.05$) numbers of live births, literacy rate and per capita income than unexposed ones, indicating that municipalities with better socioeconomic status and more live births were more likely to be introduced to ultrasound equipment during the period. Six of the 13 covariates analyzed (mothers with less than 8 years of education, single mothers, live births, literacy rate, garbage collection and per capita income) had a standard difference higher than 10 % between the two groups, which is considered undesirable for comparison (Normand et al. 2001).

Table 2 includes the municipalities after propensity score matching ($n = 310$, corresponding to 155 pairs). In this case, no covariate was considered to be statistically different between the two groups. All the standardized differences remained below the 10 % threshold. It is important to notice that the municipalities included in the final analysis were extremely poor (US$148.74 monthly per capita income for unexposed and US$149.09 for unexposed).

Table 3 shows the bias reduction for the six covariates that had a standardized difference higher than 10 % before the propensity score matching approach. The results indicate that the methodology was successful in reducing bias in every case, the most notable being number of live births where exposed had 130 more than unexposed before propensity score matching, changing to −1.6 afterwards.

We then compared the sex ratio between exposed and unexposed 1 year after the introduction of ultrasound equipment. The sex ratio for the exposed municipalities was 1.039 (95 % CI: 1.02–1.06) and for the unexposed 1.047 (95 % CI: 1.02–1.07). This resulted in a difference of 0.008, or less 0.008 male births for every female. When the paired sex ratios were compared, the difference was considered small to the point that it can be easily attributed to chance ($p = 0.65$).

Table 1 Covariate imbalance before the use of the propensity score matching approach for selected Brazilian municipalities, 2010

Covariates	Unexposed		Exposed		Difference	Standardized difference
	Mean	SD	Mean	SD		
Teenage mothers (%)	25.38	6.17	25.88	5.76	0.50	8.39
Mothers with less than 8 years of education (%)	56.21	10.76	55.09	10.68	−1.12	−10.46
Single mothers (%)	68.46	16.10	70.04	14.96	1.58	10.17
Premature births (%)	5.22	3.27	5.31	4.44	0.09	2.32
Low birth weight (%)	6.70	2.36	6.74	1.99	0.03	1.46
Live births	197.76	98.89	327.73	235.68	129.97*	71.92
Fertility	63.66	14.79	65.08	15.15	1.43	9.54
White residents (%)	25.10	10.60	25.78	10.00	0.68	6.58
Literacy rate (%)	73.84	5.61	76.00	6.78	2.16*	34.63
Residents with electricity (%)	93.50	8.47	93.47	8.03	−0.03	−0.38
Residents with garbage collection (%)	48.14	20.46	50.99	19.84	2.85	14.14
Residents with piped water (%)	58.39	20.91	57.13	20.56	−1.26	−6.08
Per capita income (BR$)	259.43	51.23	269.23	58.77	9.80*	17.77

* $p < 0.05$

Table 2 Covariate imbalance after the use of the propensity score matching approach for selected Brazilian municipalities, 2010

Covariates	Unexposed		Exposed		Difference	Standardized difference
	Mean	SD	Mean	SD		
Teenage mothers (%)	25.22	6.46	25.52	6.05	0.30	4.81
Mothers with less than 8 years of education (%)	55.62	10.52	55.54	9.77	−0.08	−0.80
Single mothers (%)	68.59	17.11	69.21	15.21	0.62	3.83
Premature births (%)	5.52	3.36	5.62	5.02	0.10	2.30
Low birth weight (%)	6.62	2.24	6.81	2.09	0.19	8.83
Live births	233.26	117.69	231.70	105.79	−1.56	−1.40
Fertility	63.20	13.91	62.73	14.07	−0.47	−3.38
White residents (%)	26.83	10.88	26.54	10.27	−0.29	−2.71
Literacy rate (%)	74.85	5.14	74.66	6.36	−0.19	−3.26
Residents with electricity (%)	93.98	8.91	93.66	8.04	−0.32	−3.75
Residents with garbage collection (%)	48.67	20.15	48.90	19.09	0.23	1.15
Residents with piped water (%)	57.31	21.92	55.83	20.83	−1.47	−6.89
Per capita income (BR$)	262.22	53.64	262.84	49.17	0.62	1.21

Discussion

Municipalities that had the introduction of ultrasound equipment had a sex ratio no different than similar municipalities that did not have the equipment during the period. In fact, municipalities with ultrasound presented a slight higher proportion of female births, albeit statistically non-significant. The inclusion of only the poorest regions of Brazil was important to test the presence of an association between extreme poverty and sex-selective abortions. Despite being considered an emerging country, Brazil has high socioeconomic differences, with its poor residents being among the poorest in the world (Milanovic 2007).

Male preference has been reported even for rich countries such as the US, even if not strong enough to induce sex-selective abortions. Dahl and Moretti (2008) found that parents who have a girl as the first-born are significantly more likely to get divorced, and women who have taken an ultrasound test are more likely to be married by delivery if expecting a boy. Mammen (2011) analyzed paternal leisure time and concluded that fathers with boys invest more time with their children than those with only daughters.

The combination of male preference and extreme poverty could lead to enough incentives to induce sex-selective abortions, but our analysis indicates that this is not the case. A literature review could also be misleading in this

Table 3 Percent reduction in bias for variables with initial standardized bias greater than 10 % for selected Brazilian municipalities, 2010

Covariates	Initial bias	Bias after matching	Percent reduction
Mothers with less than 8 years of education (%)	−1.12	−0.08	92.73
Single mothers (%)	1.58	0.62	60.76
Live births	129.97	−1.56	101.20
Literacy rate (%)	2.16	−0.19	108.74
Residents with garbage collection (%)	2.85	0.23	92.07
Per capita income (BR$)	9.80	0.62	93.65

direction, as studies that have tested the association of ultrasound equipment and presence sex-selective abortions have focused only on countries with a history of unbalanced sex ratios.

We propose here that, while there may be some economic advantages in having a male offspring in poor rural areas, sex selection will only be widespread if a combination of deep-rooted cultural reasons is present. In fact, historical and cultural preferences for males could be even more important than economic factors. This is supported by studies that analyzed sex ratios in immigrant populations living in developed countries. A study by Egan et al. (2011) of US live births, found significant difference in sex ratios for Whites (1.050) in relation to US residents of Chinese (1.078), Korean (1.071) and Asian Indian (1.066) origins. Another study by Ray et al. (2012) of live births in Ontario, Canada, also found higher sex ratios for mothers that were originally born in South Korea and India.

A limitation of this study is that it does not analyze abortions directly. As mentioned, that is due to the fact that induced abortions are illegal in Brazil. Therefore, mothers and some physicians will have an incentive to hide this information from public records and hospitals, despite death certificates being mandatory for fetal deaths. Another limitation was the use of only the poorest (mostly rural) regions of Brazil. This was needed to guarantee the existence of at least some municipalities without ultrasound equipment before 2005, but introduces a limitation of not comparing the results with more educated regions, which in India have been associated with higher sex ratios (Bhat and Zavier 2007).

Another limitation is the extrapolation of the results to other emerging countries. It is well established that many cultural and socioeconomic factors influence the practice of abortions, such as religious presence and education levels (Bartkowski et al. 2012; Sousa et al. 2010). Some characteristics of Brazil such its historical catholic influence and high illiteracy rates could make the results of the study a particular characteristic of the country.

The strength of the study comes from the fact that Brazil has a unified system of birth records with national coverage. Another important fact is that Brazilian mothers do not have an incentive to underreport female births, as is the case in China because of the One Child Policy (Wu et al. 2006).

The introduction of the propensity score matching methodology was successful in pairing municipalities with similar characteristic. The exposed and unexposed municipalities included in the final analysis had a very similar distribution of covariates, all with a standardized difference below the 10 % threshold, as suggested in the literature.

Conclusion

Concerns about an association between local poverty and sex-selective abortions should not be a barrier in slowing access to potentially life-saving maternal technology. Improvements in maternal and infant health are a part of the millennium development goals, and may be one of the hardest to achieve (United Nations 2010). While sex-selective abortions are an important concern for some countries, they are not a widespread characteristic of poverty. We propose here that the local existence of a cultural history towards male preference may be a more important factor than absolute poverty in determining the widespread practice of sex-selective abortions. Future concerns about the possibility of a direct association between poverty and sex selection should take this into consideration.

References

Bartkowski JP, Ramos-Wada AI, Ellison CG, Acevedo GA (2012) Faith, race-ethnicity and public policy preferences: religious schemas and abortion attitudes among U.S. latinos. J Sci Study Relig 51:343–358

Becker SO, Caliendo M (2007) Sensitivity analysis for average treatment effects. Stata J 7:71–83

Bhat PNM, Zavier AJF (2007) Factors influencing the use of prenatal diagnostic techniques and the sex ratio at birth in India. Econ Pol Wkly 42:2292–2303

Burgess R, Zhuang J (2000) Modernisation and son preference. Development Economics discussion paper. DEDPS 29, London

Chiavegatto Filho ADP, Laurenti R (2012) The vulnerable male, or the sex ratio among fetal deaths in Brazil. Cad Saúde Pública 28:720–728

CNES (2012a) Abrangência. Ministério da Saúde. http://cnes.datasus.gov.br/Info_Abrangencia.asp. Accessed 19 July 2012

CNES (2012b) Legislação. Ministério da Saúde. http://cnes.datasus.gov.br/Info_Legislacao.asp. Accessed 19 July 2012

Conniffe D, Gash V, O Connell PJ (2000) Evaluating state programmes: "natural experiments" and propensity scores. Econ Soc Rev 31:283–308

Dahl GB, Moretti E (2008) The demand for sons. Rev Econ Stud 75:1085–1120

Das Gupta M (1987) Selective discrimination against female children in rural Punjab, India. Popul Dev Rev 13:77–100
Das Gupta M (2010) Family systems, political systems, and Asia's 'missing girls'. Asian Popul Stud 6:123–152
Datasus (2012). Ministério da Saúde. http://www2.datasus.gov.br/DATASUS/index.php. Accessed 19 July 2012
Di Renzo GC, Rosati A, Sarti RD, Cruciani L, Cutuli AM (2007) Does fetal sex affect pregnancy outcome? Gend Med 4:19–30
Diniz D (2008) Aborto e saúde pública: 20 anos de pesquisas no Brasil. Ministério da Saúde, Brasília
Edlund L, Lee C (2009) Son preference, sex selection and economic development: theory and evidence from South Korea. Columbia University, New York
Edwards H, Thomson N (2012) Social and practical implications of fetal sex determination using ultrasound. Ultrasound 20:49–53
Egan JFX, Campbell WA, Chapman A, Shamshirsaz AA, Gurram P, Benn PA (2011) Distortions of sex ratios at birth in the United States; evidence for prenatal gender selection. Prenat Diagn 31:560–565
Frost M (2011) Fertility and the economic value of children: evidence from Nepal. University of Southampton, Southampton
Fusco CLB, Silva RS, Andreoni S (2012) Unsafe abortion: social determinants and health inequities in a vulnerable population in São Paulo, Brazil. Cad Saúde Pública 48:709–719
Ganatra B (2008) Maintaining access to safe abortion and reducing sex ratio imbalances in Asia. Reprod Health Matters 16:90–98
Harris RD, Marks WM (2009) Compact ultrasound for improving maternal and perinatal care in low-resource settings. J Ultrasound in Med 28:1067–1076
Hudson VM, Den Boer AM (2004) Bare branches: the security implications of Asia's surplus male population. MIT Press, Cambridge
IBGE (2012) Banco de dados agregados. Sistema IBGE de recuperação automática. http://www.sidra.ibge.gov.br/cd/cd2010universo.asp?o=7&i=P Accessed 19 July 2012
James WH (1987) The human sex ratio. Part 1: a review of the literature. Hum Biol 59:721–752
Junhong C (2001) Prenatal sex determination and sex-selective abortion in rural central China. Popul Dev Rev 27:259–281
Lai-wan CC, Eric B, Hoi-yan CC (2006) Attitudes to and practices regarding sex selection in China. Prenat Diagn 26:610–613
Li H, Zheng H (2009) Ultrasonography and sex ratios in China. Asian Econ Pol Rev 4:121–137
Löfstedt P, Shusheng L, Johansson A (2004) Abortion patterns and reported sex ratios at birth in rural Yunnan, China. Reprod Health Matters 12:86–95
Mammen K (2011) Father's Time investments in children: do sons get more? J Popul Econ 24:839–871
Milanovic B (2007) Global inequality: patterns and explanations. In: Held D, Kaya A (eds) Globalization and inequality. Polity Press, Cambridge
Miller BD (2001) Female-selective abortion in Asia: patterns, policies, and debates. Am Anthropol 103:1083–1095
Navara KJ (2010) Programming of offspring sex ratios by maternal stress in humans: assessment of physiological mechanisms using a comparative approach. J Comp Physiol B 180:785–796
Normand SLT, Landrum MB, Guadagnoli E, Ayanian JZ, Ryan TJ, Cleary PD, McNeil BJ (2001) Validating recommendations for coronary angiography following acute myocardial infarction in the elderly: a matched analysis using propensity scores. J Clin Epidemiol 54:387–398
Parazzini F, La Vecchia C, Levi F, Franceschi S (1998) Trends in male: female ratio among newborn infants in 29 countries from five continents. Hum Reprod 13:1394–1396
Ray JG, Henry DA, Urquia ML (2012) Sex ratios among Canadian liveborn infants of mothers from different countries. CMAJ 184:E492–E496
Rubin DB (1997) Estimating causal effects from large data sets using propensity scores. Ann Intern Med 127:757–763
Sousa A, Lozano R, Gakidou E (2010) Exploring the determinants of unsafe abortion: improving the evidence base in Mexico. Health Policy Plan 25:300–310
Tucker JD, Henderson GE, Wang TF, Huang YY, Parish W, Pan SM, Chen XS, Cohen MS (2005) Surplus men, sex work, and the spread of HIV in China. AIDS 19:539
United Nations (2010) The millennium development goals report 2010. United Nations, New York
United Nations Population Fund (2010) UNFPA guidance note on prenatal sex selection. United Nations, New York
Victora CG, Aquino EML, Leal MC, Monteiro CA, Barros FC, Szwarcwald CL (2011) Maternal and child health in Brazil: progress and challenges. Lancet 377:1863–1876
World Bank (2012) Sex ratio at birth (females per 1,000 males). http://data.worldbank.org/indicator/SP.POP.BRTH.MF. Accessed July 17 2012
World Health Organization (2011) Preventing gender-biased sex selection: an interagency statement OHCHR. WHO, Geneva
Wu Z, Viisainen K, Hemminki E (2006) Determinants of high sex ratio among newborns: a cohort study from rural Anhui province, China. Reprod Health Matters 14:172–180
Zhou C, Wang XL, Zhou XD, Hesketh T (2012) Son preference and sex-selective abortion in China: informing policy options. Int J Public Health 57:459–465