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Abstract

The stopping rule refers to a behaviour by which parents continue child bearing till they reach a specific number of children of a given gender (boys, in general). Under this behaviour, parents can choose to carry out these pregnancies to term and raise a larger number of children than originally desired. Some of these children are therefore not desired for their own sake, and can be defined as `instrumental'. When additional births become too costly, parents can also resort to sex-selective abortion by terminating pregnancies of the undesired gender. We argue that these two practices are the two complementary expressions of the stopping rule and ought to be considered under a unified framework. In this paper, we take the child as the unit of interest and propose new measures of detection of these two practices. With instrumental births, a girl is, on average, exposed to a larger number of younger siblings than a boy. Under sex-selective abortion, a boy has on average more sisters among her elder siblings than a girl. These measures are easily implementable, precise, and do not rely on a natural sex ratio. We carry out our detection tests over a large set of countries and quantify, for the countries identified by our tests, the magnitude of gender bias in parental preferences. We highlight, in particular, the minor role played by sex-selective abortion as compared to instrumental births in fertility behaviour.

JEL Classification: J13, J16, I14, O10

Keywords: N/A

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Sex-Selective Abortions and Instrumental Births as the two faces of the Stopping Rule. New measures and world evidence*

Jean-Marie Baland†, Guilhem Cassan‡ and Francois Woitrin§

March 22, 2023

Abstract.

The stopping rule refers to a behaviour by which parents continue child bearing till they reach a specific number of children of a given gender (boys, in general). Under this behaviour, parents can choose to carry out these pregnancies to term and raise a larger number of children than originally desired. Some of these children are therefore not desired for their own sake, and can be defined as 'instrumental'. When additional births become too costly, parents can also resort to sex-selective abortion by terminating pregnancies of the undesired gender. We argue that these two practices are the two complementary expressions of the stopping rule and ought to be considered under a unified framework.

In this paper, we take the child as the unit of interest and propose new measures of detection of these two practices. With instrumental births, a girl is, on average, exposed to a larger number of younger siblings than a boy. Under sex-selective abortion, a boy has on average more sisters among her elder siblings than a girl. These measures are easily implementable, precise, and do not rely on a natural sex ratio. We carry out our detection tests over a large set of countries and quantify, for the countries identified by our tests, the magnitude of gender bias in parental preferences. We highlight, in particular, the minor role played by sex-selective abortion as compared to instrumental births in fertility behaviour.

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Keywords: sex-selective abortion, stopping rule, gender discrimination

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1 Introduction

Strong preference for sons is prevalent in many societies. Many cultural factors account for these gender biased preferences, including patrilocality (Ebenstein, 2014), old age support (Ebenstein and Leung, 2010; Lambert and Rossi, 2016), or the burden of the dowry (Arnold et al. (1998), see also Williamson (1976), Das Gupta et al. (2003) or Jayachandran (2015) for detailed reviews). In this paper, we explore the demographic consequences of these preferences.

Gender biased preferences lead to two fertility practices: the *"stopping rule"*, by which parents continue having children until they reach their desired number of boys[1] and *"sex-selective abortion"*, by which parents abort foetuses of the undesired gender. Both practices are viewed as distinct consequences of son preference and tend therefore to be investigated separately by the literature (Arnold, 1985; Basu and de Jong, 2010; Bhalotra and Cochrane, 2010; Jayachandran, 2015). Figure 1 presents the number of papers in Jstor in which the words "stopping rule" alone, "sex-selective abortion" alone, and both combined appear at least once.[2] A vast majority of papers mention only one practice, with no reference to the other. The stopping rule has also become of marginal interest as compared to sex-selective abortion. A plausible reason for this evolution is the belief that sex-selective abortion has led to the disappearance of the stopping rule. As we will show below, this belief is, to a large extent, wrong. Another possible reason is that the consequences of sex-selective abortion are thought to be more problematic than those of the stopping rule, which is highly debatable. A third reason is methodological, as sex-selective abortion distorts the observed sex ratios, making their use unfit for detecting the stopping rule.

In this paper, we argue that sex-selective abortion is not fundamentally distinct from the stopping rule. When focussing on pregnancies, sex-selective abortion and the stopping rule are essentially equivalent. Figure 2 describes the pattern of pregnancies for families which desire one son and no daughter, with or without sex-selective abortion. In both cases, their behaviour is identical: they carry on having pregnancies when the foetus is a girl and they stop having pregnancies when the foetus is a boy.[3]

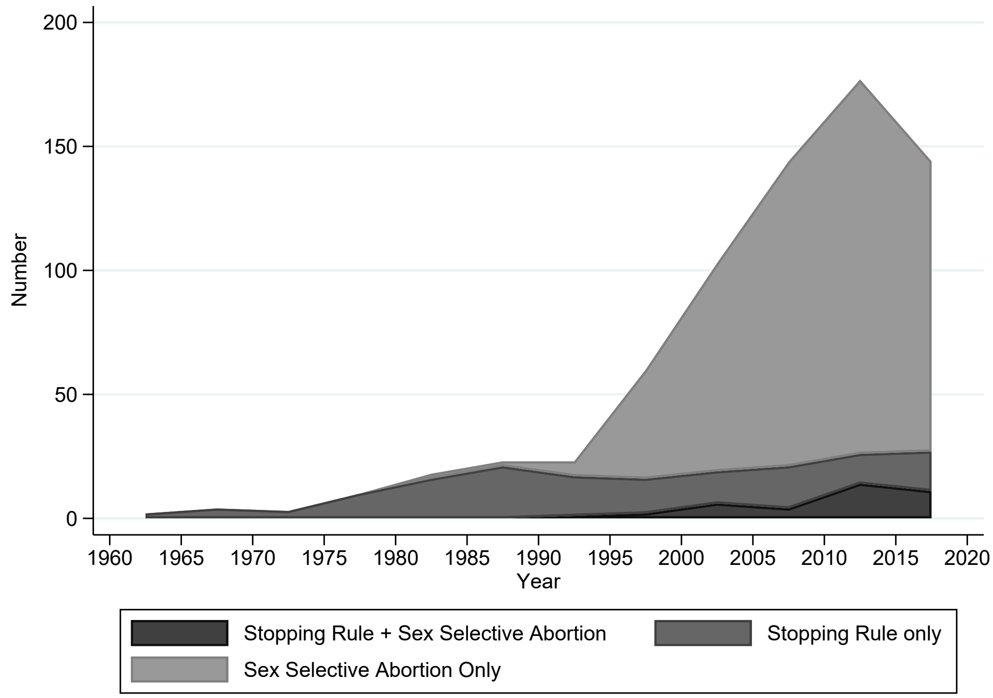
In the following, *"stopping rule"* is used to refer to the general practice of childbearing until the desired gender composition is reached. This practice is made of two components: *"instrumental birth"* and *"sex-selective abortion"*. *"Instrumental birth"* describes this behaviour by which parents have children until the

[1] The preferred gender is boy in most cases, so, for simplicity, we refer to boys only, whereas these practices could also be used to target a desired number of girls.

[2] As "stopping rule" is also a term widely used in computer sciences, we have added the word "fertility" to all those searches. There exist also several synonyms to "stopping rule", which we have included in our searches The searches made were: "stopping rule" OR "differential fertility behavior" OR "son-targeting fertility behavior" OR " son-preferring fertility behavior" NOT "sex-selective abortion" ; "sex-selective abortion" NOT "stopping rule" NOT "differential fertility behavior" NOT "son-targeting fertility behavior" NOT "son-preferring fertility behavior" ; "sex-selective abortion" AND "stopping rule" ; "sex-selective abortion" AND "differential fertility behavior" ; "sex-selective abortion" AND "son-targeting fertility behavior" ; "sex-selective abortion" AND "son-preferring fertility behavior" . All articles found in duplicates were removed. These searches were conducted on January 9, 2023. Non relevant results referring to agricultural practices were manually cleaned.

[3] Obviously, girls are born in one case and aborted in the other.

Figure 1: Number of articles referring to gender biased fertility practices.



Data source: Jstor and author's computations.
Reading: in 2000-5, out of 103 articles published mentionning the words "stopping rule" (and its synonyms) or "sex-selective abortion", 84 mentionned sex-selective abortion alone, 13 mentionned "stopping rule" alone and 6 mentionned both.

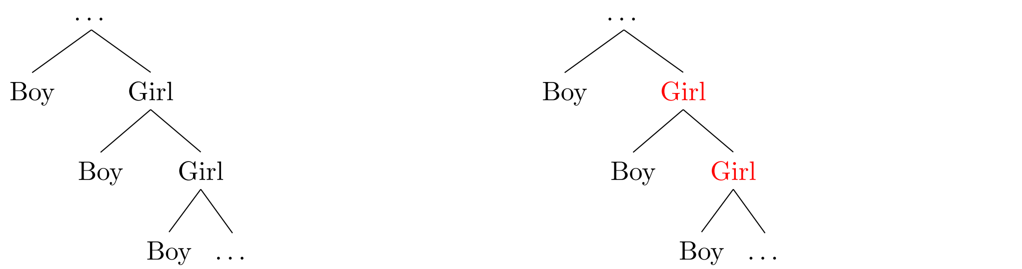
desired gender composition is reached.[4] Under this behaviour, children of the undesired gender are born. They are instrumental since their birth happened only as a result of their parents' attempt to get a child of the desired gender.[5] *"Sex-selective abortion"* refers to the practice of terminating pregnancies until reaching the desired gender composition. To our knowledge, the stopping rule has never been considered under that light.

We analyze these two components under a unified framework: under the stopping rule, sex-selective abortion and instrumental birth are the two technologies households can use to reach their desired gender composition. When the sex-selective technology is not available, parents carry on having pregnancies and children. When sex-selection technology is available and cheap enough, parents carry on having pregnancies but terminate some of them. When costs are intermediate, sex-selective abortion does not fully replace instrumental births and the two technologies are used within the same family. In this case, parents resort to instrumental births for their first pregnancies while switching to sex-selective abortions for the last ones. Once having chosen sex-selective

[4] This is the practice the literature generally refers to when using the term "stopping rule".

[5] Some authors refer to these children as undesired children. We believe that, ex-ante, parents practicing instrumental births know that they require these births in order to attain their desired gender composition. Therefore, these births are better termed 'instrumental' than 'undesired'. Ex-post, of course, these children may be undesired.

Figure 2: Sex-selective abortion as a stopping rule: an illustration.



(a) Pregnancies without sex-selective abortion

(b) Pregnancies with sex-selective abortion

abortion, parents never switch back to instrumental births.

Given this equivalence, studying these two technologies jointly is important because of the policy trade-offs involved. They are indeed associated with undesirable, but different, outcomes. On the one hand, instrumental births lead to higher than desired fertility (Sheps, 1963; Park, 1978, 1983; Arnold, 1985; Clark, 2000; Dahl and Moretti, 2008; Basu and de Jong, 2010). It is the source of negative outcomes at the level of the society (fertility is higher than desired), the mother (for instance, through increased maternal mortality (Milazzo, 2018)) and the girl (by exacerbating sibling competition, reducing birth intervals or via other forms of differential treatment (Arnold et al., 1998; Jensen, 2003; Bhalotra and van Soest, 2008; Jayachandran and Kuziemko, 2011; Rosenblum, 2013; Rossi and Rouanet, 2015; Altindag, 2016; Jayachandran and Pande, 2017)). On the other hand, sex-selective abortion controls fertility but leads to missing girls at birth (Sen, 1990; Anderson and Ray, 2010; Bhalotra and Cochrane, 2010; Anukriti et al., 2022): too few girls are born as compared to boys. Abortions are costly for mothers and involve highly skewed sex ratios at the society level (Tuljapurkar et al., 1995; Hesketh and Xing, 2006; Bhaskar, 2011; Edlund et al., 2013; Grosjean and Khattar, 2018). By contrast, girls, once born, are more likely to be desired and face better outcomes than under the stopping rule (Goodkind, 1996; Lin et al., 2014; Hu and Schlosser, 2015; Kalsi, 2015; Anukriti et al., 2022).

Unless gender biased preferences are changed, a policy which increases the cost of sex-selective abortion (Nandi and Deolalikar, 2013) leads to more instrumental births. Without entering into an 'optimal population' debate, it is not clear that, given the implications for mothers, children and the society, this particular policy is desirable per se. While changing the relative costs of these technologies may not necessarily be feasible or desirable (as discussed in Das Gupta (2019), see also Mohapatra (2013)), we emphasize here their substituability, whereby a policy targeting one technology has direct consequences on the prevalence of the other. Sex-selective abortion is forbidden in many countries (Darnovsky, 2009), rising the cost of sex-selective abortion compared to instrumental births, and inducing parents to turn to instrumental births. By contrast, some countries impose strict limits on the number of births, such as the one child policy in China, increasing the realtive cost of instrumental births and inducing parents to turn to sex-selective abortions. This policy trade-off is absent from many debates about these practices.

Under our unified framework, we derive tests allowing to detect instrumental births and sex-selective abortions and quantify their relative prevalence. Our detection tests do not rely on the benchmark provided by a natural sex ratio.[6] They can be applied without any further assumption or prior knowledge about gender preferences. They are also robust to the distortions in the sex ratio induced by sex-selective abortion, as well as to underlying differences in the natural sex ratio at birth.[7] As we elaborate below, this makes our tests more reliable than existing alternatives.[8] As stressed above, these tests are important from a policy perspective as they allow the detection of both instrumental births and sex-selective abortions, and therefore inform policy makers, researchers and activists about where to target their efforts, both geographically or in terms of the technology used. In addition, our quantification exercise shows that instrumental births remain largely prevalent, even in contexts in which sex-selective abortions are widely practiced. Thus, in Haryana, an Indian state known for the high prevalence of sex-selective abortion, instrumental births are twice as prevalent as sex-selective abortion (out of the 22% of children directly affected by the stopping rule, 15 percentage points are born via instrumental births while the remaining 7 percentage points are missing due to sex-selective abortion).

The main intuitions behind these tests are as follows. Were data on pregnancies and the gender of foetuses available to the researcher, detecting and measuring the stopping rule, instrumental births and sex-selective abortions could be done jointly. However, because data on pregnancies are typicaly not available, measuring instrumental births and sex-selective abortions has to be done through two separate, though related, approaches. They are defined at the child level and are both based on the information available in the demographic composition of the siblings.

Building on Yamaguchi (1989), Arnold et al. (1998) and Ray (1998), we show that, under the stopping rule and a preference for sons, female foetuses are on average followed by more pregnancies than male foetuses, but they have the same number and gender distribution of previous pregnancies foetuses. In the absence of sex-selective abortion, this translates into girls having on average more younger siblings than boys, but having the same number and gender distribution of elder siblings. Our formalization, while taking the perspective of the child rather than that of a family with a completed fertility, replicates some well-known consequences of instrumental births: total fertility is higher than desired (Sheps, 1963), the total number of siblings is higher for girls than for boys (Yamaguchi, 1989; Basu and de Jong, 2010) and, within families, the average birth order of girls is lower than for boys (Basu and de Jong, 2010). As a matter of fact, all these are the direct consequences of girls having more younger siblings than boys under the stopping rule. Our child level approach

[6] See the discussion in Anderson and Ray (2010) on the absence of a universal natural sex ratio.

[7] See the discussion in Anderson and Ray (2010) on how Sub Saharan Africa countries seem to have a different natural sex ratio at birth and how this may lead to very large underestimation of the phenomena of missing women at the world level if not properly taken into account.

[8] Bongaarts (2013)'s international study of sex ratio at birth and of sex ratio of the last born for example can not distinguish between changes in natural sex ratio across space and time and changes in sex ratio caused by sex-selective abortion.

makes formalization much simpler as well as more precise than previous attempts, and therefore contributes to the large theoretical literature on instrumental births.[9]

This result also suggests a simple method to identify countries (or societies in general) in which instrumental births prevail, by detecting countries in which girls have more younger siblings than boys. Compared to other methods such as the sex ratio of the last born (Jayachandran, 2015), there is no need to refer to a natural sex ratio at birth, which has been shown to vary across time and space (Chahnazarian, 1988; Waldron, 1998; Bruckner et al., 2010) and cannot provide a reliable benchmark as discussed in Anderson and Ray (2010). This property also makes our test robust to the practice of sex-selective abortion, which directly affects sex ratios. Our method can also be applied to families which have not completed their fertility and thereby allow us to consider recent, instead of past, behaviours (Haughton and Haughton, 1998). As we will show, besides countries in South Asia and Northern Africa, many Central Asian and European countries do implement a stopping rule.

Over the recent years, the practice of sex-selective abortion developed rapidly as a method to control the gender composition in the family. As abortions are typically not observable, the literature focusses on the evolution of the sex ratio at birth over time and birth ranks (Park and Cho, 1995; Arnold et al., 2002; Hesketh and Xing, 2006; Jha et al., 2006; Almond and Edlund, 2008; Abrevaya, 2009; Bhalotra and Cochrane, 2010; Jha et al., 2011; Chen et al., 2013; Lin et al., 2014; Anukriti et al., 2022). This literature exploits the empirical fact that sex-selective abortion tends to be practiced at later birth ranks: it looks at how the sex ratio at birth changes across ranks before and after the arrival of sex-selection technology. In doing so, this literature implicitely relies on the fact that, under son preference, sex-selective abortion is more likely the larger the proportion of girls among elder siblings.[10] We develop a formalization of this insight, showing that parents always prefer to postpone sex-selective abortions and turn to them when unsatisfied with the gender composition of their first births. When instrumental births and sex-selective abortions are not too costly, parents will use both: they will start with instrumental births and switch to sex-selective abortions in later births. This is because the opportunity cost of instrumental births discontinuously rises in the last births, when the birth of an instrumental girl would prevent the family from reaching its desired number of sons. This suggests a simple test of detection based on the proportion of girls among elder siblings. Absent sex-selective abortion, the proportion of boys and girls among elder siblings should be independent of the gender of the child. When sex-selective abortion is widespread, the gender composition of elder siblings differs: a girl is more likely to be born (aborted) when parents are (not) satisfied with the gender composition of her elders, that is, if she has a large proportion of boys (girls) among her elder siblings. As a result a difference in the proportion of boys among elder siblings

[9]For example the influential formalization of Basu and de Jong (2010) concludes that instrumental births lead to two distinct consequences: that girls have more siblings (as in in Yamaguchi (1989)) and that girls have a higher birth order within family. They also write that "girls will be born into relatively larger family." Our approach shows that there are not two but only one consequence of instrumental births: girls have more younger siblings (but the same number of older siblings). As a consequence, girls are not born in family larger than boys: at birth, their family is exactly as large as those of boys. But their families will grow larger after their birth. Only our child level approach can make that point formally.

[10]Figure 2 in Anukriti et al. (2022) provides a nice graphical illustration of this pattern.

across genders is evidence of sex-selective abortion. As in the detection of instrumental births, this test does not rely on the use of a natural sex ratio.[11] Countries that practice sex-selective abortion are essentially located in South and Central Asia and Eastern Europe.

We then calibrate a simple model of gender-biased desired fertility to decompose the stopping rule into instrumental births and sex-selective abortions. This approach provides a measure of the proportion of 'instrumental' children which, as we show, is large and biased against girls. Given the general decline in desired fertility, it also tends to increase over time. In the process, we compute a 'desired' sex ratio, defined as the ratio of the desired number of boys to that of girls, to assess gender biased preferences. Following Anderson and Ray (2010), we also provide a measure of 'missing' girls at birth and show that instrumental births remain the most prevalent stopping rule technology even in the presence of widely available sex-selection methods. Among countries practicing the stopping rule, we show that focusing on sex-selective abortion alone leads to an under estimation of the consequences of the stopping rule by more than 66%.

The structure of the paper is as follows: we first present our formalization of instrumental births and of sex-selective abortion. Following the detection methods developed in that section, we then identify the countries in which the instrumental births or sex-selective abortion prevail, and quantify their prevalence. We discuss that type of data needed for our tests to be used and show that while fertility history data is ideal, our tests do reasonnably well with household roster data even in the presence of patrilocality and gender difference in age of marriage. Finally, we compare the result of our test to those obtained under more traditional measures and discuss these alternative approaches.

2 Demographic consequences of the stopping rule

2.1 The stopping rule and the number of younger siblings

In its analysis of the consequences of instrumental births, the theoretical literature in demography has extensively focussed on outcomes at the family level, such as the total fertility or the sex ratios among children (e.g Sheps (1963); Yamaguchi (1989); Clark (2000); Basu and de Jong (2010)). Our approach differs by taking the perspective of an individual child and by considering the stopping rule at the level of pregnancies rather than actual births. This perspective drastically simplifies the modeling effort and delivers more precise empirical predictions. It also highlights the equivalence between the two technologies behind the stopping rule.

The main intuition of our measure goes as follows: suppose that the only reason for which parents have pregnancies is to reach a desired number of boys. Each pregnancy is considered as a draw in a lottery in which having a male foetus is a "success", while having a female foetus is a "failure". When a male is "drawn", parents

[11] Apart from the difficulty linked to the absence of a benckmark natural sex ratio, the use of the sex ratio as birth to detect sex-selective abortion has been criticized (Dubuc and Sivia, 2018) for offering a potentially biased view of the *proportion* of parents willing to use it to reach their desired number of sons, in the presence of decreasing desired fertility.

are one unit closer to their objective. When a female is "drawn", parents make no progress, and additional pregnancies (draws) are required in order to compensate for this failed attempt - no matter whether the foetus is sex-selectively aborted or not. This is true at each pregnancy. Therefore, compared to a male, a female foetus is a failed lottery draw, which does not contribute to the desired number of boys. As a result, a female foetus of a particular rank will be followed by exactly the same number of pregnancies as a male foetus of the same rank plus the expected number of additional draws required to have the male foetus that she is not.

We now formally investigate this mechanism. Consider first the case under which couples can have an unlimited number of children and want to have a given number b^* of boys. At any pregnancy, parents have p chances to have a boy and $(1-p)$ chances to have a girl. As a result, in a 'large' population and at each pregnancy, there is exactly $\frac{1-p}{p}$ female foetus for each male foetus. In other words, the (male to female) sex ratio at any rank in this population is constant and equal to $\frac{p}{1-p}$. The 'stopping rule' has no effect on the sex ratio in the aggregate or at each rank (Sheps, 1963). (Of course, by its very definition, the stopping rule determines the gender of the last birth and therefore the sex ratio of the last pregnancy.)

By definition, the mothers of a male or of a female foetus of pregnancy k had the same number of $k-1$ pregnancies in the past. The gender composition of these past pregnancies is also identical, as it is independent of the gender of the k^{th} foetus itself. For instance, if we assume that parents want at least 3 boys and focus on a foetus at rank 3, there are four possible combinations for the previous pregnancies: $(female - female, female - male, male - female, male - male)$. These events occur with probability $\left((1-p)^2, (1-p)p, p(1-p), p^2\right)$, which is the distribution faced by a foetus at rank 3, independently of whether it is a female or a male. As a result, the only difference between male and female foetuses of the same rank comes from subsequent pregnancies. The critical difference between the two is the fact that having a male foetus at a particular rank implies that parents are one unit closer to their desired number of boys. Having had a female, parents are not closer to their target and, therefore, need additional pregnancies to compensate. Therefore, at any given rank, a female foetus is expected to be followed by more pregnancies than a male. Let us now assume, more realistically, that the number of children born in a family cannot exceed a given maximum, $\bar{N}$, with $\bar{N} > b^*$. This additional constraint implies that, absent sex-selective abortion, some families will not reach their desired number of boys. Consider a foetus of rank k and of gender $i = b, g$ who has e older brothers, with $e + 1 \leq b^*$ (the last inequality indicates that, at rank $k-1$, the family has not yet reached her desired number of boys, b^*). We denote by $E\left(Y_i\left(k, e\right)\right)$ the expected number of pregnancies that follow a foetus of rank k^{th}. Following the discussion above, we obtain:

Proposition 1: For any number of elder brothers e, with $e + 1 \leq b^*$, the expected number of future pregnancies is strictly larger for a female than for a male foetus at any rank k, with $k < \bar{N}$:

$$E\left(Y_g\left(k,e\right)\right) > E\left(Y_b\left(k,e\right)\right),\ \forall k < \bar{N}, e+1 \leq b^*.$$

Moreover,

$$E\left(Y_g\left(k,e\right)\right) - E\left(Y_b\left(k,e\right)\right) = 1/p,\ \forall e+1 \leq b^*, \quad \text{when} \quad \bar{N} \to \infty.$$

Proof: See Appendix A

The proposition remains true, independently of the technology available to parents. In particular, when sex-selective technology is not available, this implies that, at a given birth rank, girls have, in expected terms, more younger siblings than boys. As the proposition holds for each rank, we also have, by summing over all ranks, that girls on average have a larger expected number of younger siblings. This result easily extend to a situation under which parents also desire a given number of daughters $g^* > 0$. A preference for boys in this situation simply requires that the desired sex ratio, b^*/g^*, is larger than $p/(1-p)$. Under this condition, girls still have more younger siblings. To the best of our knowledge, no other plausible mechanism can produce such an outcome.

It is easy to show that the difference in the expected number of subsequent pregnancies is increasing in $\bar{N}$. More precisely, for a given number of desired boys, b^*, the difference at any rank $k < \bar{N}$ is monotonically increasing in $\bar{N}$, as does the male to female ratio of the last pregnancy. Conversely, for a given $\bar{N}$, the difference is monotonically decreasing in the number of desired boys, b^*. Moreover, when $\bar{N}$ is very large, the difference takes a very simple expression. Having had a female instead of a male foetus, parents need one more boy in the future to compensate and therefore require, in expected terms, $1/p$ more pregnancies. As a result, at any given rank, the mother of a female foetus is expected to have $1/p$ additional pregnancies. In particular, if $p = 1/2$, she will, on average, have 2 more pregnancies than if the foetus had been a boy.[12] [13]

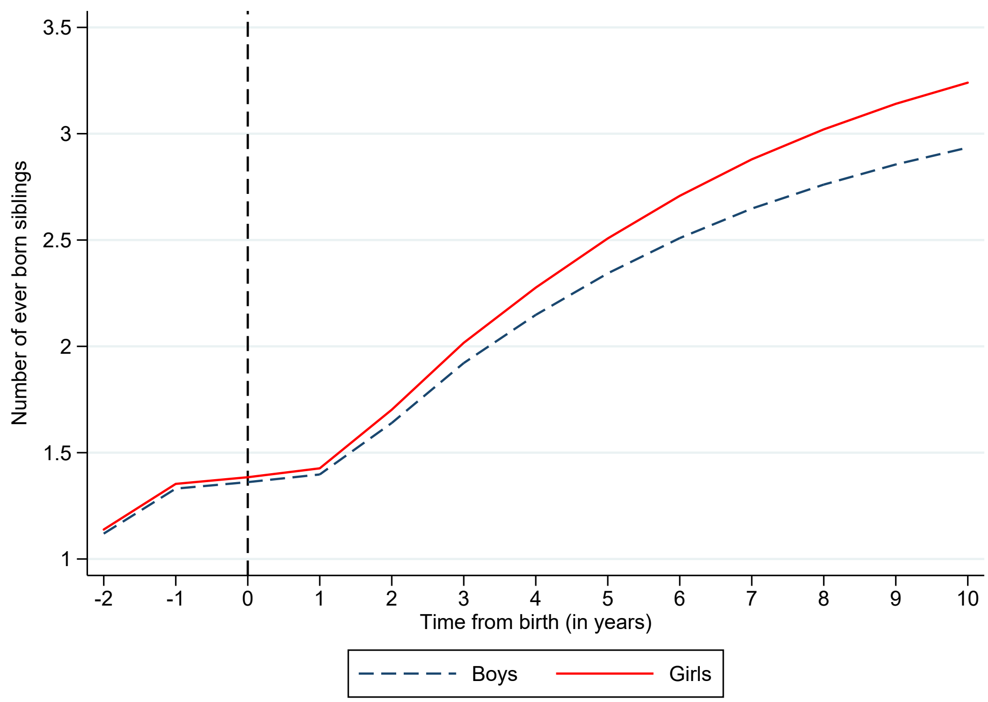
Figure 3 illustrates the model's main prediction with Indian data, India being a country in which the stopping rule is considered as pervasive. For all children who are at least 10 years old at the time of the survey, we have computed, at each age between -2 and 10, the average number of ever-born siblings for boys and girls separately. Before being born (at age -2 to 0), Indian boys and girls have the same number of (ever-born) older siblings. It is only after their births that the number of siblings for a girl becomes higher than for a boy, the more so the older she gets[14].

[12] These results closely parallel those of Yamaguchi (1989), who investigated the impact of the stopping rule on the expected proportion of boys in a family and total family size. We show here that these outcomes can only be driven by younger siblings.

[13] Note that a similar result can be found using an alternative model in which parents have lexicographic preferences over the number of children and the number of sons. Interestingly, a lexicographic model of the stopping rule demonstrates that the fertility squeeze (Guilmoto, 2009; Jayachandran, 2017) not only applies to sex-selective abortions but also to instrumental births. See Appendix B for more details.

[14] Note that if a child is not yet born (negative ages), she can only have elder siblings but when she is born (positive ages), her

Figure 3: Number of ever-born siblings by age and gender in India



Data source: DHS India 1993, 1999, 2006, 2015, all children aged 10+ at the time of the survey.
Reading: at age 10, the average Indian girl has 3.24 ever-born siblings and the average Indian boy has 2.93 ever-born siblings.

2.2 Self-selective abortion and the composition of elder siblings

Detecting instrumental births is relatively straightforward, given the availability of data on birth history. A different approach is needed to detect sex-selective abortion since reliable information on pregnancies and abortions is not available. Suppose again that parents can have a maximum of $\bar{N}$ children. To simplify the discussion, we assume here that parents want exactly b^* boys and no girls, with $\bar{N} > b^*$. As discussed later, the argument easily extends to the more general setting in which $g^* > 0$. The 'natural' probability of having a boy out of each pregnancy is given by p. Each abortion implies a cost to parents of C_{ssa}, and girls have no value per se. In this simple framework, parents will always delay abortion as long as this is feasible, i.e., as long as the number of possible births left allows them to achieve their objective of b^* boys. Indeed, abortion at pregnancy j implies a cost of C_{ssa} while, by postponing to the next rank, this cost only occurs with probability $(1 - p)$. In other words, future abortions are, in expected terms, always less costly than the current one. This implies that, once a couple decides to practice sex-selective abortion, other abortions are also carried out in the future

siblings will be either older or younger siblings. Therefore, the fact that the divergence in the number of ever born siblings emerges only after the child is born reflects that the divergence is driven *only* by younger siblings.

in the event of other female foetuses. We therefore have:

Lemma: Once, for a given pregnancy, sex-selective abortion is chosen, sex-selective abortion is chosen for all future pregnancies.

In families which only had daughters in their previous pregnancies, the result above implies that, since parents want b^* boys, sex-selective abortion starts to be applied at birth rank $\bar{N} - b^* + 1$. More generally, for those families that did yet not achieve their desired number of boys, female foetuses are systematically aborted at all pregnancies for which the number of births left available corresponds to the number of boys that are still missing to reach their objective. In particular, full sex-selection is expected in the last rank, $k = \bar{N}$. In other words, at each rank $k \geq \bar{N} - b^* + 1$, sex-selective abortion is applied by some families to obtain some of the boys born at that rank.

That sex-selective abortion is applied at later ranks is supported by a large body of evidence (see e.g. Lin et al. (2014)). Figure 4 illustrates this idea in the case of Armenia. We report in the Figure the average sex ratio for all births of a particular rank, before and after the widespread utilization of the ultra-sound technology (2000). While before 2000, their sex ratio does not vary across ranks, the picture after 2000 is particularly striking, with a steep increase in the observed ratio in the later ranks. Thus, the sex ratio at rank 4 reaches 164, implying a proportion of boys in all births of rank 4 of 62.1%. By contrast, the sex ratio at rank 1 is identical to that prevailing before 2000, indicating a negligible amount of sex-selective abortion at that rank.

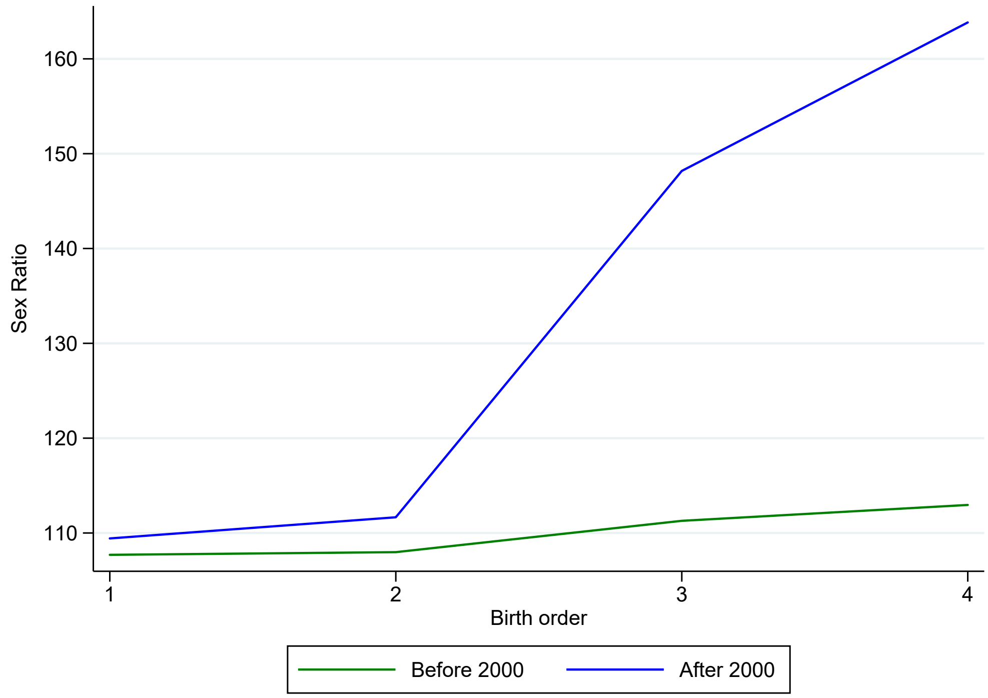
An important implication from the above argument is that sex-selective abortions are practiced in families with not enough sons and too many daughters. This observation implies that, for all boys of rank $k \geq \bar{N} - b^* + 1$ the proportion of girls among their elder siblings is larger for a boy than for a girl of the same rank.[15]

Proposition 2: Under self-selective abortion, at any rank $k \geq \bar{N} - b^* + 1$, the proportion of girls among elder siblings is larger for a boy than for a girl.

The proposition is at the heart of our test to detect the occurrence of sex-selective abortion. The argument easily extends to a setting in which parents also want a given number of daughters. As a matter of fact, even if gender preferences are biased in favour of girls, so that $b^*/g^* < p/(1-p)$, the proportion of boys among elder siblings is larger for a girl than for a boy, so that the proportion of girls among elder siblings is again larger for a boy than for a girl. As a result, the proposition simply states the consequences of biased preferences, regardless of the preferred gender. Finally, in the particular case in which $b^* + g^* = \bar{N}$, sex-selective abortion is already practiced in the first rank.

[15]Note that the probability that the sibling of rank $k-1$ is a girl is also larger than for a girl of the same rank. Also, the proportion of girls among younger siblings is lower for girls than for boys of a given rank.

Figure 4: Sex ratio at birth by birth rank in Armenia before and after 2000



Data source: DHS Armenia 2000, 2005, 2010 and 2016, all children born at the time of the survey.
Reading: Prior to 2000, the sex ratio at birth at rank 3 is 111. After 2000, it is 148.

2.3 Combining Costly Instrumental Births and Sex-Selective Abortion

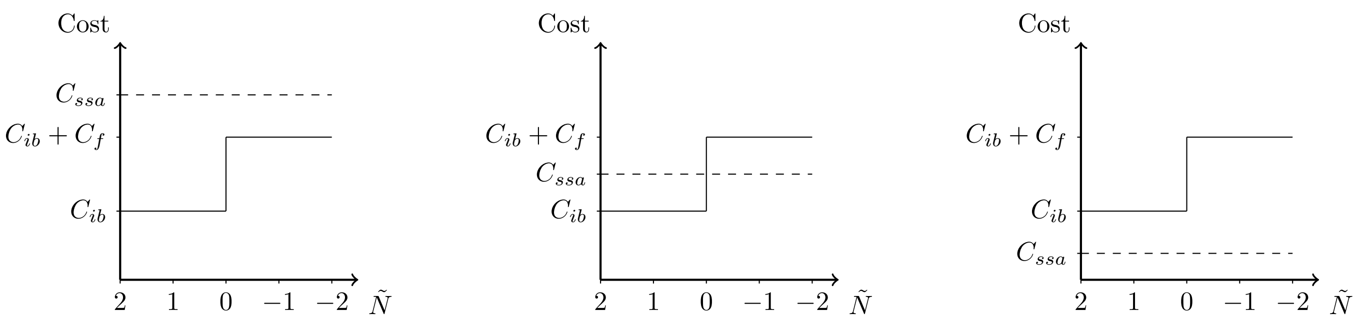
As argued above, instrumental births and sex-selective abortions are two complementary mechanisms driving the demographic composition of families. When sex-selective abortion becomes available, parents choose the best practice by comparing the cost of abortion to the cost of an (additional) instrumental child. We consider the case in which $\bar{N} > b^* + g^*$ and, for simplicity, we assume that all costs are constant. As above, C_{ssa} stands for the cost of abortion, while the cost of an instrumental birth is given by C_{ib}. We also have to consider the additional cost of failing to reach the desired gender composition, which we denote by C_f. This cost occurs when the number of births left available is lower or equal to the number of boys or girls that still remain to be born. In other words, the cost of instrumental births changes discontinuously when it comes at the cost of not reaching the desired gender composition: the first instrumental births are relatively cheap draws, the last instrumental births are expensive draws, while sex-selective abortions are a costly way to cheat the lotery.

Comparing these costs, three cases are possible. In the first case, $C_{ssa} > C_{ib} + C_f$ at all ranks, and abortions, being too costly, are never practiced. When $C_{ssa} < C_{ib}$ at all ranks, abortion is cheaper than an additional instrumental child, and parents always resort to sex-selective abortions for each foetus of the undesired gender.

More interesting is the case in which the cost of an abortion is smaller than the combined costs of an instrumental birth and of not reaching the desired gender composition for some ranks, $C_{ib} + C_f > C_{ssa}$, but greater than the cost of an instrumental birth at lower ranks: $C_{ssa} > C_{ib}$. In this case, parents choose instrumental births for the first pregnancies and switch to sex-selective abortions at later ones, when the number of births left available is just equal to the number of desired boys or girls still required.

As the cost of sex-selective abortion falls, its prevalence increases as parents turn away from carrying out to term their last pregnancies. These cases are illustrated in Figure 5, where $\tilde{N}$ represents the number of 'cheap draws'.[16] When abortion costs are small and lower than C_{ib} at all ranks, sex-selective abortion is practiced from the first pregnancy on, all born children are of the desired gender and no instrumental births occur (Figure 5c). By contrast, when abortion costs are very large, sex-selective abortion is never practiced and, at each rank, part of the births are "instrumental" (Figure 5a). Policies affecting the number of sex-selective abortions will therefore result in opposite changes in the number of instrumental births. This framework also accomodates policies controlling the number of births allowed to parents. For example, the "One child policy" in China makes $\tilde{N} \leq 0$.

Figure 5: Technology choice as a function of relative costs and 'cheap' draws



(a) Only Instrumental Births

(b) Instrumental Births followed by Sex-selective Abortions

(c) Only Sex-selective abortions

Sex-selective abortions do not therefore imply the disappearance of instrumental births. In the case illustrated in Figure 5b, parents in early ranks prefer to carry out the pregnancies while turning to sex-selective abortions in later ranks when these become necessary to reach their desired target. To illustrate this case, consider a family which desires two boys and one girl, with $p = 1/2$ and $\bar{N} = 5$. Among all possible family compositions, suppose that we observe the following sequence : girl, girl, boy, girl and finally a boy. Among these children, the girl born at rank 2 is 'instrumental' since she was not desired per se, but is born as the

[16]Formally, $\tilde{N} = \underbrace{(\bar{N} - k + 1)}_{Remaining\ draws} - \underbrace{(max(0, b^* - b) + max(0, g^* - g))}_{Remaining\ required\ successes}$, with b and g the number of boys and girls already obtained at that rank and b^* and g^* the desired number of boys and girls.

result of the parental desire to have two boys. Similarly, the girl at rank 4 is also instrumental. Finally, at the last rank, parents, having had three girls and one boy, will abort in the event of a female foetus. As a result, the boy born at the last rank is either the result of a natural birth, with probability p, or of an abortion with probability $1-p$.[17] In other words, $1-p$ girls should have been born in the last rank, have been replaced by a boy and should be considered as 'missing'. Among these five births, we therefore have two 'instrumental' and $1-p$ 'missing' children.

Two measures of interest can be defined here. The first one is the *share of instrumental births*, defined as the number of instrumental births divided by the total number of children, and which we interpret as the probability that a child taken at random is 'instrumental'. The second is the *share of missing children*, defined as the number of births that would have been of a different gender in the absence of abortion, again divided by the total number of pregnancies. It corresponds to the probability that a random child is born as the result of at least one previous abortion.

It is worth noting that, under the assumptions made above, the sum of these two measures is exactly equal to the share of instrumental births that would have occurred in the absence of abortion. This is because our measure of missing children does not (and cannot) measure the actual number of abortions, which remain unobserved, but, instead, the number of foetuses ('potential' instrumental children) that have been replaced by a child of the desired gender. Absent abortion, these foetuses would be born and counted as instrumental births. For instance, in our simple numerical example, consider the set of families of five children starting with a sequence (g, g, b, g) for the first four children. In the absence of abortion, a proportion $(1-p)$ of families present the sequence (g, g, b, g, g) and a proportion p of families, (g, g, b, g, b). On average, therefore, $2+(1-p)$ children are instrumental. When abortion is available, the last female foetus is replaced by a male in $(1-p)$ families, and the only sequence observed is (g, g, b, g, b), with two instrumental children and $(1-p)$ missing girl, which corresponds exactly to the $(1-p)$ instrumental child above. This property strikingly illustrates this idea that instrumental births and sex-selective abortion are the two complementary dimensions of the stopping rule.[18]

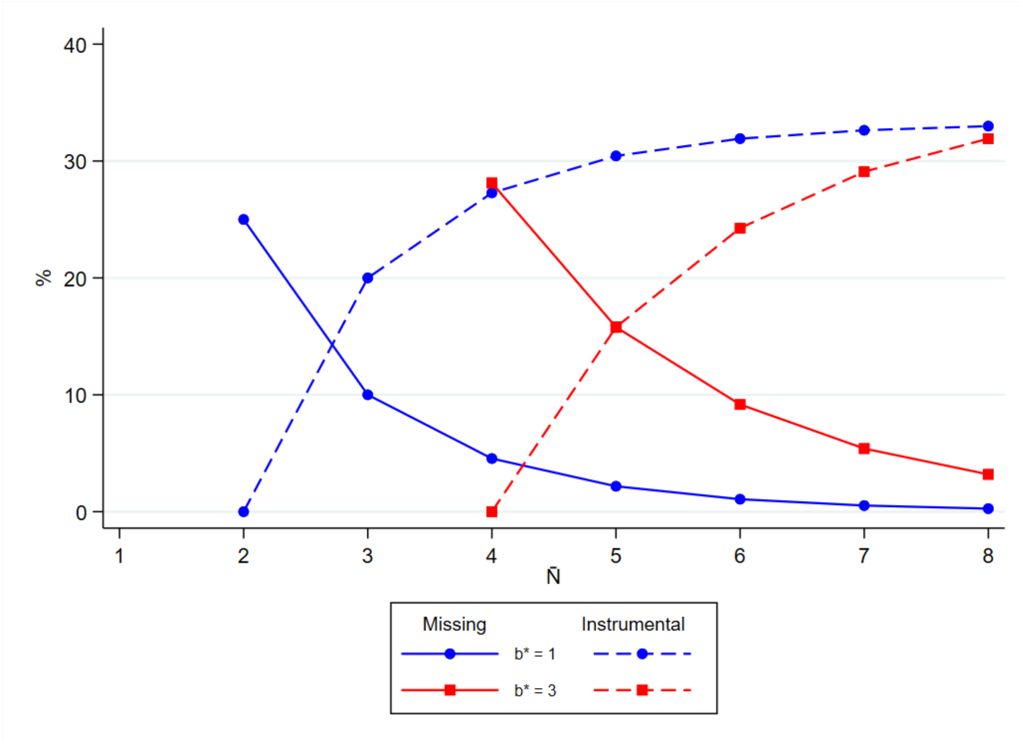
Even when sex-selective abortions substitute for instrumental births, the latter remain quantitatively significant. To illustrate this point, we computed the share of instrumental births and missing children observed in families that desire 1 girl and either 1 or 3 boys, with a probability $p=0.5$. Figure 6 presents the evolution of the two measures for different levels of the maximum number of children (up to 8).

Even if abortion is available, the share of instrumental births remains sizeable and, in general, exceeds the

[17] Strictly speaking, in this case, multiple abortions are possible in the event of a sequence of female foetuses (Dimri et al., 2019). We therefore implicitly assume that parents can have a large number of pregnancies, even though the maximal number of children is given. Under this assumption, we can infer the corresponding expected number of abortions necessary to obtain the boy who replaces the 'missing' girl at rank 5 as $1/(1-p)$. As a result, the expected number of abortions in the last rank is exactly equal to 1 $(=(1-p)*1/(1-p))$. If the number of possible pregnancies is limited, the expected number of abortions lies between $(1-p)$ and 1. Note that, given the Bernoulli process assumed, this expected number quickly converges to 1, even for a limited number of pregnancies. Thus, if at most six pregnancies in the last rank are possible, the corresponding expected number of abortions is larger than 0.98.

[18] This property holds as long as the availability of abortion does not change the actual number of births, nor the desired number of boys and girls. Our assumptions of given preferences and of a given maximum family size satisfy these two requirements.

Figure 6: Decomposition of stopping rule between instrumental births and missing births



Data Source: Author's simulations.
Reading: For a desired number of boys b^* of 1, of girls g^* of 1 and a maximum number of births $\bar{N}$ of 3, there are on average 30% of children born under the stopping rule: 20% because of instrumental births and 10% because of sex-selective abortions.

share of missing children. Thus, when parents desire 3 boys and 1 girl, with a maximum family size of 6, the share of instrumental births is equal to 24.3% (out of which 22.5% are instrumental girls and 1.8% instrumental boys) while the share of missing births is equal to 9.2% (out of which 8.9% are missing girls and 0.3% missing boys). In the absence of abortion, one would have observed 33.5% instrumental children. Also, the share of 'missing' children becomes quickly negligible when the family size is large. For instance, focusing again on the case in which parents desire 3 boys and 1 girl, the share of missing children falls down to 3.2% when the maximum family size is equal to 8 (as compared to a share of instrumental births equal to 31.2%). It is only when the number of desired boys and girls is very close to the maximum number of children that the share of missing births gets relatively large. Thus, when parents can have up to 5 children, the share of missing and the share of instrumental children are both equal to 15.8%. By construction, when the desired number of boys and girls is exactly equal to the maximum family size, no instrumental births are observed and the share of missing children is equal to 28.1%.[19]

[19] This is in line with (Jayachandran, 2017) who highlights the increased occurrence of abortions under declining fertility. In the context of our model, we indeed observe an increase in the share of missing children, and therefore in the occurrence of abortion, as the maximum family size decreases.

3 Prevalence of the stopping rule across countries

Given the demographic consequences of the stopping rule, our theory offers a precise and straightforward strategy to detect and measure the prevalence of the stopping rule, without relying on partial evidence or priors about the prevailing practices. We first derive detection tests based on the sibling composition of each child. For instrumental births, our test measures the number of younger siblings she has while, for sex-selective abortion, we focus on the gender composition of her elder siblings. We present our main results at the world scale, before proposing measures of the relative importance of instrumental and missing children in countries that implement the stopping rule. We finally provide a more detailed analysis of the Indian case.

In our empirical analysis, we use the Demographic and Health Survey (DHS) of all countries available. This represents 82 countries, 2,995,509 mothers and 10,361,884 births. The DHS are particularly valuable to us as they are comparable across countries, and record the fertility history of ever married women aged 13 to 49. We can therefore reconstruct for each child at any age the number of siblings, older or younger, she had. Appendix D lists the countries and surveys we used, as well as the corresponding number of observations. For the detection of sex-selective abortion, we focus on children born after 2000, since the ultra-sound technology was not widespread enough before that date. This restricts our sample to 1,685,160 mothers and 3,754,614 births in 69 countries.[20]

3.1 Detecting the stopping rule

3.1.1 Instrumental Births

As shown in the preceding section, the difference in the number of younger siblings between girls and boys of any rank is exactly zero in the absence of stopping rule. This benchmark does not depend on a natural sex ratio, nor on whether a particular child is a last born or not. Our measure of instrumental births simply compares the difference in the number of younger siblings of girls and boys to this logical benchmark. When instrumental births prevail in favour of boys, this difference is necessarily greater than zero. When favoring girls, this difference is smaller than zero. As discussed in Section 2, it can also be aggregated across children and families in a straightforward manner.

To illustrate our approach, we run the following estimations for India and Bolivia:

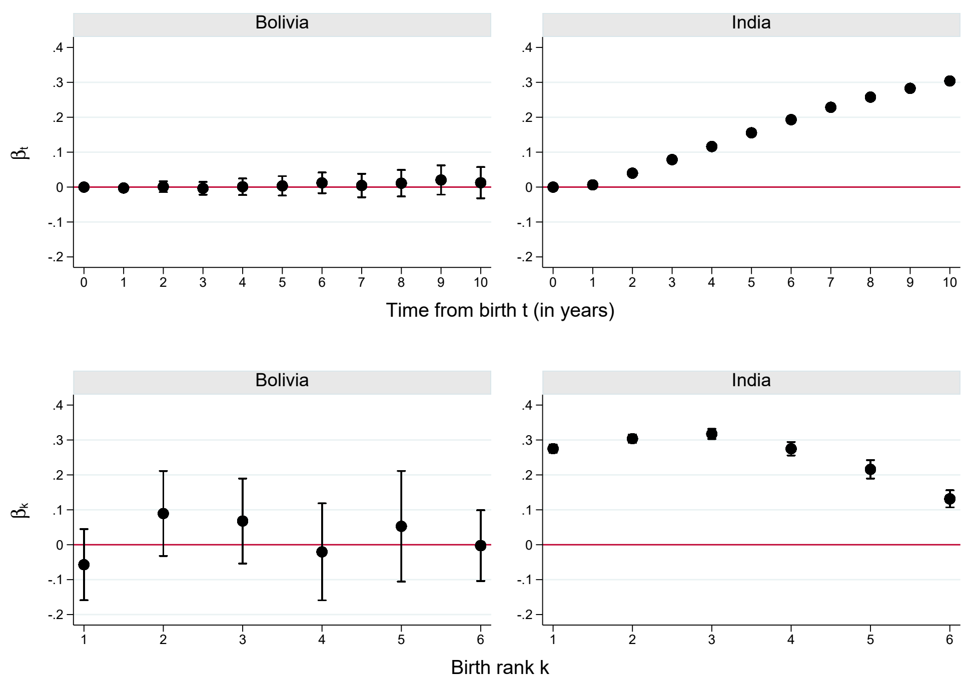
$$nb\_younger\_siblings_{it} = \sum_{t=0}^{T} (\alpha_t * age_{it} + \beta_t * female_i * age_{it}) + \epsilon_{it} \tag{1}$$

$$nb\_younger\_siblings_{ik} = \sum_{k=1}^{K} (\alpha_k * rank_{ik} + \beta_k * female_i * rank_{ik}) + \epsilon_{ik} \tag{2}$$

[20] Ideally, we would have liked to also analyze the cases of Korea, Japan, Taiwan or China. Unfortunately, appropriate data were either not available or not directly comparable to the information provided by the DHS.

where $nb\_younger\_siblings_{it}$ is the number of ever born younger siblings of child i at age t and $nb\_younger\_siblings_{ik}$ is the number of ever born younger siblings of child i at rank k. For each child between zero and ten year old or between rank 1 and 6, we record all her younger siblings at each age, with an age or rank-varying number of younger siblings. (We also cluster standard errors at the primary sampling unit and weight each observation by the DHS sample weight.) As our estimates describe parental preferences, there is no *a priori* reasons to include additional controls in the specifications. Figure 7 below reports our estimates.

Figure 7: Differential number of ever-born younger siblings by age and rank, India and Bolivia



Data Source: DHS Bolivia 1989, 1994, 1998, 2003 and 2008 and DHS India 1993, 1999, 2006 and 2015.
Reading: In India, at age 10, girls have on average 0.3 more younger siblings than boys of the same age. Girls born at rank 5 have on average 0.24 more younger siblings than boys of the same rank. No difference across gender is perceivable either by age or by rank in Bolivia.

Figure 7 strikingly illustrates the prevalence of instrumental births in India, as the number of younger siblings at all relevant ages or ranks is systematically larger for girls than for boys. (These results replicate, in a regression format, the descriptive statistics presented in Figure 3 above.) As expected, this differential increases with age, to reach an average of 0.3 extra siblings at age 10. By contrast, for ranks, the relation is non-monotonic as the number of additional children declines at higher ranks. We also report the corresponding estimates for Bolivia, for which no such differential exists. At any rank, at any age, the average Bolivian girl has the same number of younger siblings as the average Bolivian boy.

We now provide the test for the prevalence of instrumental births across all the countries surveyed. Since the difference in the number of younger siblings prevails at all ranks and ages, we use equation 3 to estimate for each country a condensed version of equations 1 and 2[21]:

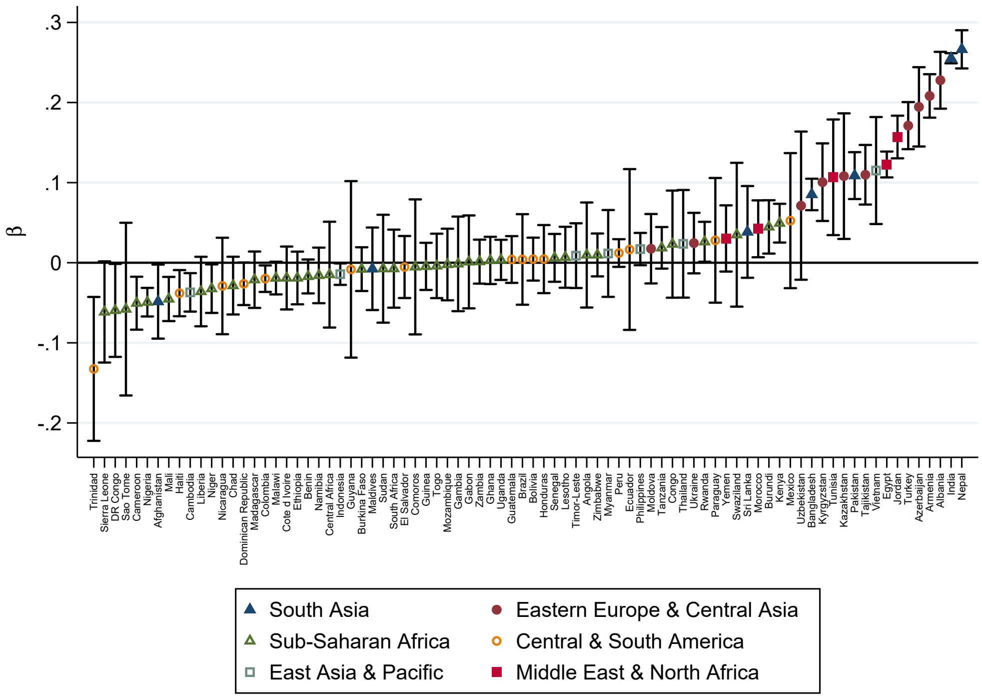
$$nb\_younger\_siblings_i = \beta * female_i + \epsilon_i \quad (3)$$

The coefficient β corresponds to the difference in the average number of younger siblings a girl faces compared to a boy. Two additional remarks are in order. First, as illustrated by Figure 7, one could use children of a particular age to carry out our test. When measuring the difference in the number of younger siblings at younger ages, the measure is increasingly influenced by birth spacing which may vary across gender (see in particular Jayachandran (2015)). This in itself is not a issue for a measure of detection of the instrumental births, as shorter birth spacing associated with the less desirable gender simply translates into a larger number of younger siblings at a young age. On the other hand, focussing on older children implies that our measure applies only to a more distant past and does not provide information on more recent years. Given these two trade-offs, we choose here to focus on all children, but our main results are robust when focussing on children of a specific age. Second, one could also choose a particular rank over which to apply our measure and focus, for instance, on the eldest child of each family. In theory, a test on the difference in the number of younger siblings between first-born girls and boys provides a necessary and sufficient condition for the detection of the instrumental births. This is because the gender composition of younger siblings is given by a probability distribution so that a test on the eldest child carries enough information for the test to apply and requires only to know the gender of the eldest child and the number of younger siblings. In doing so however, we neglect useful information related to the consequences of the gender of siblings of higher ranks. In a 'small' sample, focussing on a particular rank therefore provides a sufficient but not a necessary test of the instrumental births.

We report in Figure 8 the differential number in younger siblings of girls for all countries present in our sample, by increasing order. On the right-hand side of the Figure, one finds a substantial cluster of countries with a very high difference in the number of younger siblings, indicating the prevalence of instrumental births in these countries. The latter does not only include the 'usual suspects', such as Nepal, India, Pakistan or Bangladesh, but also countries of Eastern Europe and Asia, such as Albania, Turkey, Armenia, Azerbaijan, Jordan, Kazakhstan, Kyrgyzstan, Tajikistan or Vietnam, and Northern Africa, such as Egypt, Morocco or Tunisia. This fact has been essentially ignored by the economic literature (Ebenstein (2014) is a notable exception). Second, a few countries (Cambodia, Cameroon, Colombia, DR Congo, Haiti, Indonesia, Mali, Niger, Nigeria and Trinidad), display a much smaller (in absolute value) but negative coefficient, suggesting the

[21] Note that, when aggregating over all ranks, the average birth order of girls is lower than that of boys (Basu and de Jong, 2010). Not controlling for ranks therefore makes our measure higher (in absolute value). Since the 'aggregate-rank' effect is a direct consequence of instrumental births, and as our measure solely aims at detecting the prevalence of instrumental births, this is not an issue.

Figure 8: Differential number of ever-born younger siblings of girls, by country



Data Source: All DHS.
Reading: In Nepal, girls have on average 0.27 more younger siblings than boys.

presence of a stopping rule favoring girls and not boys.[22] This possibility is hardly mentioned in the economic literature (Williamson, 1976), but our gender neutral approach allows to identify such a case. Most countries from Sub-Saharan Africa do not apply the stopping rule. (This last statement has to be qualified, however, owing to the relative prevalence of polygamy in most of these countries. This may have implications that we discuss in the subsection 3.2.)

3.1.2 Sex-selective Abortion

Our measure of sex-selective abortion compares at the child level the gender composition of his or her elder siblings and does not require a particular benchmark, such as the one given by a 'natural' sex ratio.[23] When sex-selective abortion does not apply, the gender distribution among elder siblings is identical across boys and girls of any rank so that no difference can emerge. By contrast, when sex-selective abortion applies, boys tend to

[22] This pattern is grossly consistent with countries in which brideprice- rather than dowry - is practiced, such as in Indonesia (Ashraf et al., 2020) or Sub Saharan African countries (Corno et al., 2020)

[23] An alternative measure could simply focus on the gender of the preceding child, but this strategy does not use the full information available to the parents at the time of pregnancy. While less efficient, it also provides a sufficient condition for detecting sex-selective abortion.

have more sisters and girls more brothers among their elder siblings.[24] The prevalence of sex-selective abortion can be illustrated using the following estimation:

$$sh\_elder\_girls_{it} = \sum_t (\gamma_t * year_{it} + \delta_t * male_i * year_{it}) + \epsilon_{it} \quad (4)$$

where $sh\_elder\_girls_{it}$ is the share of sisters among alive elder siblings of a child i born in year t.[25] Note that, unlike our detection test for instrumental births, the coefficient of interest does not vary with age. This is because the composition of the elder siblings is given and does not vary with the age of the child. By contrast, we carry out our estimations at different birth years t so as to compare the current situation to that prevailing before the spread of ultra-sound technologies. Alternatively, we can also estimate the prevalence of sex-selective abortion for children at specific ranks k over a given period:

$$sh\_elder\_girls_{ik} = \sum_k (\gamma_k * rank_{ik} + \delta_k * male_i * rank_{ik}) + \epsilon_{ik} \quad (5)$$

Focussing again on India and Bolivia, the top panel of Figure 9 below presents our estimates over several birth cohorts starting in the mid-seventies. On the bottom panel, we report the corresponding estimates for children of different ranks born after 2000.

As in the analysis of instrumental births, India and Bolivia offer a contrasting image. While Bolivia appears essentially gender neutral, with no noticeable differences between girls and boys, India exhibits a strong prevalence of sex-selective abortion for all ranks once the ultra-sound technology became widely available at the end of the nineties. Since then, the incidence of sex-selective abortion increases monotonically.

We now provide a test of sex-selective abortion across all countries which, for the sake of presentation, is based on a simplified version of equation 5, averaging over all ranks:

$$sh\_elder\_girls_i = \delta * male_i + \epsilon_i \quad (6)$$

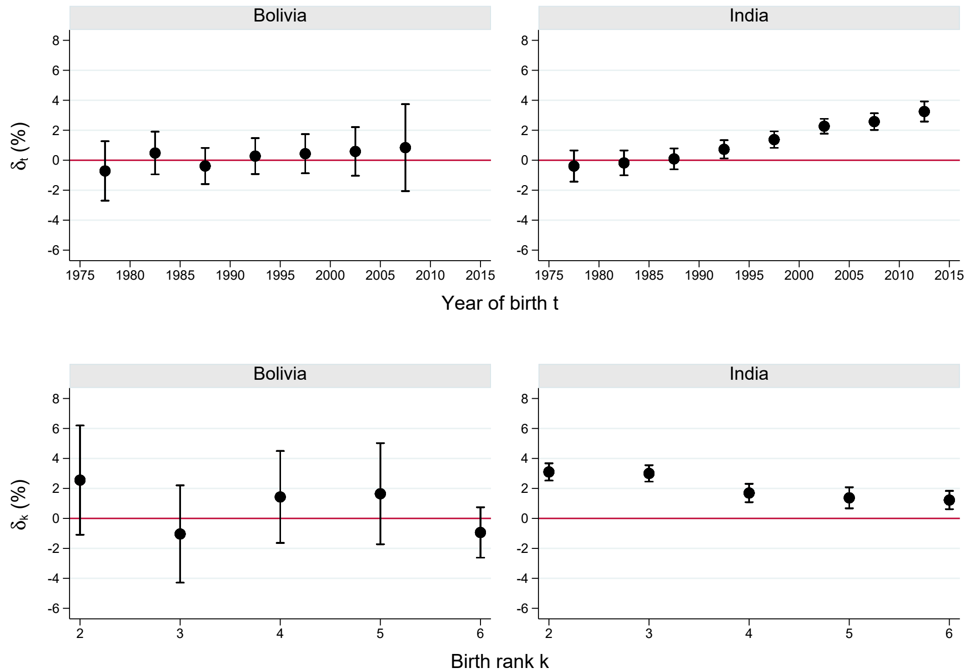
The δ coefficient, estimated separately for each country, corresponds to the difference after 2000 in the average proportion of girls among elder siblings of girls as compared to boys. Figure 10 presents these estimates by increasing order of magnitude.

On the right-hand side of the Figure, we find the countries with a significant difference in the gender composition of elder siblings. As expected, these are less numerous than in the detection of instrumental births, owing to the limited availability of the ultra-sound technology. Among the countries identified, one finds India,

[24] Note that it is also the case that boys have more sisters among their younger siblings compared to girls. Nevertheless, even when sex-selective abortion is not applied, the gender distribution among younger siblings is not the same for boys and girls, as girls have more younger siblings under the stopping rule. This may become a problem in small samples.

[25] Given that the decision to abort selectively depends on the composition of the family at the time of the pregnancy, we focus on elder siblings alive at the time of birth.

Figure 9: Differential share of girls in elder siblings by period and rank, India and Bolivia



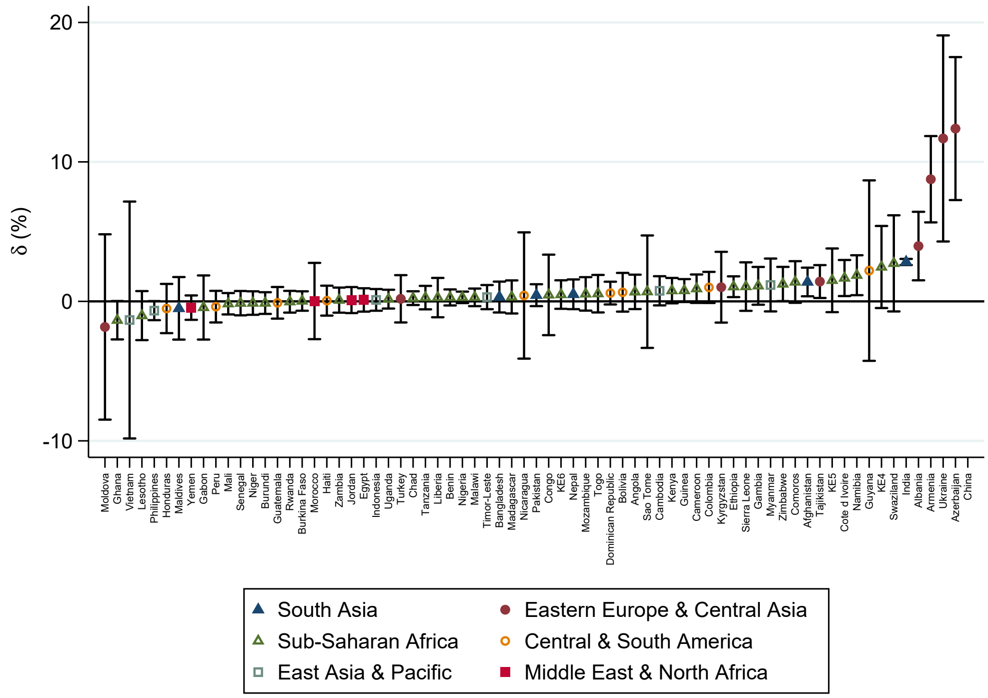
Data Source: DHS Bolivia 1989, 1994, 1998, 2003 and 2008 and DHS India 1993, 1999, 2006 and 2015.
Reading: In India, from birth cohort 1990 onwards, boys start having a larger proportion of girls among their elder siblings than girls. There is no such difference in Bolivia. For births taking place after 2000 in India, at each birth rank, boys have a larger proportion of girls among their elder siblings than girls. There is no such difference in Bolivia.

Albania, Armenia, Azerbaidjan and Tajikistan in which the stopping rule also prevails, but also Ukraine. At much lower levels of significance, one also finds Cote d'Ivoire, Ethiopia, Namibia and Zimbabwe. As discussed in Section 3.1, our measure remains silent as to whether sex-selective abortion favors a particular gender. The observed sex ratio is needed to infer the prevailing gender bias.

3.2 Limits of our approach

We now discuss more systematically these two tests. The measures we propose are by themselves meaningful. Thus, our test of instrumental births directly provides a measure of the number of additional siblings and, therefore, the sibling competition a girl is exposed to compared to a boy. Our test of sex-selective abortion is a direct measure of gender diversity within families. However, in terms of gender preferences, our measures do not lend themselves to straightforward interpretations. They indeed take values that depend on the desired number of boys and girls as well as the maximal family size, which vary across time and space. As a result,

Figure 10: Differential share of girls in elder siblings of boys, all countries



Data Source: All DHS, births taking place after 2000.
Reading: In Azerbaidjan, boys have on average a proportion of girls among their elder siblings larger by 12.39 percentage points as compared to that of girls.

our measures cannot be directly used to compare the intensity of gender preferences across countries.[26] In this respect, our measures therefore only provide sufficient conditions for the prevalence of instrumental births and sex-selective abortions.

Second, our measures only capture biases in gender preferences. For instance, if families have the same desired number of boys and girls ($\frac{b^*}{g^*} = \frac{p}{1-p}$), no differential across gender can arise and our two measures are equal to zero. As a result, a non-conclusive detection test cannot differentiate between families that have no preference regarding the gender of their children and families that apply the stopping rule to achieve an equal number of boys and girls. A similar remark holds if, in the population, parents have opposite gender preferences, with about half of them applying the stopping rule in favour of boys and the other half in favour of girls. Clearly, all widely used tests also suffer from this shortcoming. What we actually detect through our tests is whether preferences are on average biased towards a particular gender in a population.

Third, our two measures should be implemented concurrently in order to assess the prevalence of the stopping rule, as they refer to two separate mechanisms of the same fundamental behaviour. Moreover, since sex-selective

[26] As discussed in McClelland (1979), this qualification also holds for other classical measures, such as the parity progression ratio.

abortion tends to be applied at later ranks, it does not neutralize the consequences of the stopping rule in earlier ranks but makes instrumental births increasingly harder to detect empirically at later ranks. By contrast, instrumental births have, by themselves, no impact on the detection of sex-selective abortion since they cannot affect the gender composition of older siblings.

An additional difficulty comes from the possibility of a selective recall bias. Under-reporting children has two consequences on our measures: on the one hand, when computing our measures on children of rank k, some children of rank k are missing, which leads to missing observations in that rank and a possible selection bias; on the other hand, those children will not be accounted for when computing our measures on their siblings; leading to a measurement bias. As long as the recall bias is gender neutral, so that boys are as likely to be under-reported than girls, some observations are missing, but our measures remain unbiased. In demographic surveys, the main recall bias come from under-reporting elder girls who died in early age. In our measure of instrumental births, these 'forgotten girls' reduce the number of younger siblings of their elders by the same amount, independent of their gender. As a result, the difference in the number of younger siblings of these elders remains unchanged. There is therefore no measurement bias at this level. However, some elder girls, with a larger number of younger siblings, are systematically not accounted for (the selection bias). This biases downwards our measure, which still provides a sufficient condition for the prevalence of instrumental births.

Concerning sex-selective abortion, there are no clear reasons to believe the recall bias to cause a systematic selection bias in our estimates, as long as the girls unaccounted for present a gender distribution among their elder siblings that is similar to that of an 'average' girl in the sample. For children that are observed, however, there are good reasons to believe that these 'forgotten' girls affect differently the gender composition of elder siblings. One indeed expects underreporting to be more frequent in families with a stronger son preference. In these families, the under-reported girls tend to be followed by more younger brothers. The fall in the proportion of girls in elder siblings therefore affects the observed boys much more than the observed girls. As a result, boys on average present an even lower proportion of sisters in their elder siblings compared to girls of the same rank, leading to a downward bias of our measure. Our test again provides a sufficient condition.[27] We also discuss in Appendix C the impact of other potential observational biases on our tests, as those present in household rosters which systematically omit elder children living outside the household.

Finally, our two measures are not appropriate in all settings. First, they require parents to have on average more than one child. Our measures can not be used to analyze, for instance, the one child policy in China and its demographic consequences.[28] The sex ratio at birth, with all its shortcomings, turns out to be the only measure available. Second, our test for instrumental births applies essentially to monogamous societies. In

[27] By contrast, traditional measures based on the observed sex-ratio are systematically affected by this under-reporting, over-estimating the occurrence of sex-selective abortion.

[28] This limitation also holds for all measures relying on family size to detect instrumental births (such as the parity progression ratio or the measures proposed by Basu and de Jong (2010); Yamaguchi (1989); Rossi and Rouanet (2015)) or on ranks to detect sex-selective abortion (Bhalotra and Cochrane, 2010).

polygamous settings, one cannot exclude the possibility that men having a strong preference for boys choose to have more children with the wife that give them a son at first birth. Under this argument, mothers with a female first born have fewer children and boys, on average, end up having a larger number of younger siblings than girls. (This however points to a limitation of regular surveys which do not collect systematic information on the father of the child.)

3.3 Measuring the prevalence of the stopping rule

We now intend, on the basis of the previous estimates, to quantify the prevalence of the stopping rule. We want, in particular, to estimate (1) the gender bias in abortion rate and the resulting share of missing children, (2) the desired fertility by gender, and in particular, the difference between the number of desired boys and the number of desired girls and, finally, (3) the share of instrumental children by gender. As is now clear, our previous tests do not provide by themselves such indicators and we need to compute these relying, on the one hand, on a particular value of the natural sex ratio and, on the other hand, on a simple model that structures parental preferences. We assume this model to be common for the set of families under analysis (e.g. a country over a given period). After describing our empirical strategy, we first present the estimated temporal evolution of some critical indicators for India. We then provide a summary table of these indicators for all the countries in which a gender bias was detected through our two tests, before returning to the Indian case, which we investigate in more details by state and caste.

3.3.1 Empirical Approach

We first measure sex-selective abortion by comparing a natural sex ratio to the observed sex ratio, along the spirit of the methodology proposed by Anderson and Ray (2010). Note that this simple comparison does not provide an estimate of the total number of abortions per gender, since these cannot be inferred using the actual number of children born by gender. We are therefore unable to estimate for each gender separately the number of abortions or 'replacements' that may have occurred. What we can do instead, through this comparison, is to estimate the excess number of 'replacements' against a particular gender as compared to the other. For the sake of presentation, we again assume that abortion rates are biased against girls, so that this comparison provides us the share of missing girls. Let N_b and N_g stand for the observed number of boys and girls. We first compute, given the number of existing children, the counterfactual population of girls which we should observe under the natural sex ratio, where p stands for the 'natural' probability of a boy at each birth. We refer to this number as the potential population of girls, N_g^P, defined as follows:

$$N_g^P = (1 - p)(N_b + N_g)$$

This expression allows us to define the share of missing girls at birth among all children, m_g:

$$m_g = \frac{N_g^P - N_g}{N_b + N_g}$$

For instance, suppose that we observe in a population of 200 children 110 boys and 90 girls. With a natural sex ratio of 100 girls for 100 boys, we should have observed a potential population of 100 girls, and the proportion of missing girls is then equal to 10/200, that is 5%.[29]

In a second step, we measure the share of instrumental children, by estimating the desired number of boys and girls. In order to do so, we calibrate a simple model of a representative household which would like to have a given number of boys, b^*, and a given number of girls, g^* for a maximum family size given by $\bar{N}$. We define X as the total number of births necessary to obtain b^* boys and g^* girls, given a probability of male birth equal to p. Under a discrete approach, the probability distribution of X is the sum of two truncated negative binomial distribution, and is given by the following expression[30]:

$$P(X = x|b^*, g^*, p) = \binom{x-1}{b^*-1} p^{b^*}(1-p)^{x-b^*} + \binom{x-1}{g^*-1}(1-p)^{g^*} p^{x-g^*}$$

$$\text{for} \quad x \in \mathbb{N} \in \{b^* + g^*, \bar{N}\} \quad \text{and} \quad b^*, g^* \geq 1$$

The first term of this expression represents the probability to have $b^* - 1$ boys in the first $x - 1$ births and a boy at the x^{th} birth. The second term similarly represents the probability to have $g^* - 1$ girls and b^* boys in the first $x - 1$ births, and a girl at the x^{th} birth. In the following, we rely on a continuous version of this expression, in which $b^*, g^* \in \mathbb{R}_+$ and the binomial coefficients are replaced by Gamma functions:

$$f_X(x; b^*, g^*, p) \propto \frac{\Gamma(x)}{\Gamma(b^*)\Gamma(x - b^* + 1)} p^{b^*}(1-p)^{x-b^*} + \frac{\Gamma(x)}{\Gamma(g^*)\Gamma(x - g^* + 1)}(1-p)^{g^*} p^{x-g^*}$$

$$\text{for} \quad x > b^* + g^* \quad \text{and} \quad b^*, g^* \geq 0$$

Under this expression, the distribution of the number of younger siblings for boy (X_b) of the a first rank is given by $f_{X_b}(x; b^* - 1, g^*, p)$. Similarly, the distribution of the number of younger siblings for a girl (X_g) of the first rank is given by $f_{X_g}(x; b^*, g^* - 1, p)$.[31] Our empirical strategy relies on the fact that the number of younger siblings of the first born, given his (her) gender, provides all the information needed in terms of

[29] The proportion of missing girls computed here differs from that in Anderson and Ray (2010) since we compute the number of girls that should 'replace' boys under the natural sex ratio instead of the additional number of girls that should have been born given the number of boys observed. We therefore rely on the actual population as a natural benchmark, keeping total population fixed, while they consider a potential population of children that should be alive but are not observed. The rationale for using a measure of potential population in Anderson and Ray (2010) lies in their focus on adult excessive mortality, while our measure of instrumental children, used later, requires us to focus on children that are actually born.

[30] Note that when the desired number of children of one gender, g^* for instance, is equal to 0, the probability distribution of X reduces to a simple negative binomial distribution with parameters b^* and p.

[31] Strictly speaking, one needs to add a normalizing multiplicative constant for this expression to integrate to 1. This constant, which we will estimate, depends on b^* and g^* but quickly converges to 1 for large enough values of b^* or g^*.

family size and composition (given the distribution above). This property is directly related to our previous observation according to which focussing on the first born is, in a large sample, necessary and sufficient for the detection of the stopping rule. We first compute μ_b and μ_g, the average number of younger siblings for first-born boys and girls observed in the sample. Given a large enough number of observations, we know that $\mu_b \to E(X_b|b^* - 1, g^*, p)$ and $\mu_g \to E(X_g|b^*, g^* - 1, p)$, the expected number of younger siblings for a first-born boy or girl given the distribution above. Given particular values of p and $\bar{N}$, we then compute the expected value of X_b and X_g for all possible values of b^* and g^*.[32] We then select the values of b^* and g^* which minimize the distance between the observed means μ_i and the corresponding expected values $E(X_i)$ for $i = b, g$, where the distance is defined as the sum of the differences in absolute value. To obtain the number of instrumental children of a particular gender, we simply compute the difference between the actual and the desired number of children.[33]

3.3.2 Measuring instrumental and missing births across countries

We start by illustrating the evolution of gender preferences in India. For that country, we compute the desired numbers of children by gender, over intervals of five years starting in 1975 (corresponding to the year of birth of the child concerned). Figure 11 below presents the estimated desired total fertility (by summing the number of desired boys and girls) on the left axis as well as the the proportion of desired boys among these, which is a direct measure of gender biased preferences (on the right axis).

Over the whole period, desired fertility decreased in India in which it fell from about 3.3 in 1980 to 1.75 in the recent years. The proportion of desired boys in total desired fertility is relatively stable at around 60%, which corresponds to a 'desired' sex ratio of 150 boys for 100 girls $(0.57/(1 - 0.57))$.

We then compare the desired to the actual number of girls and boys and compute the share of instrumental boys and girls. We also compute the share of missing girls at birth using each country's pre-1980 sex ratio as estimated in Chao et al. (2019) as the natural sex ratio at birth.[34] Figure 12 reports for an average family the number of desired and instrumental children, separately for boys and girls, as well as the number of missing girls. Over the whole period, the desired number of boys and girls decreased monotonically, while the number of instrumental children remains constant, which implies that the share of instrumental boys and girls increased throughout. As expected, girls are also more likely to be instrumental. Starting after 1990, the share of missing girls at birth is by contrast modest and remains stable.

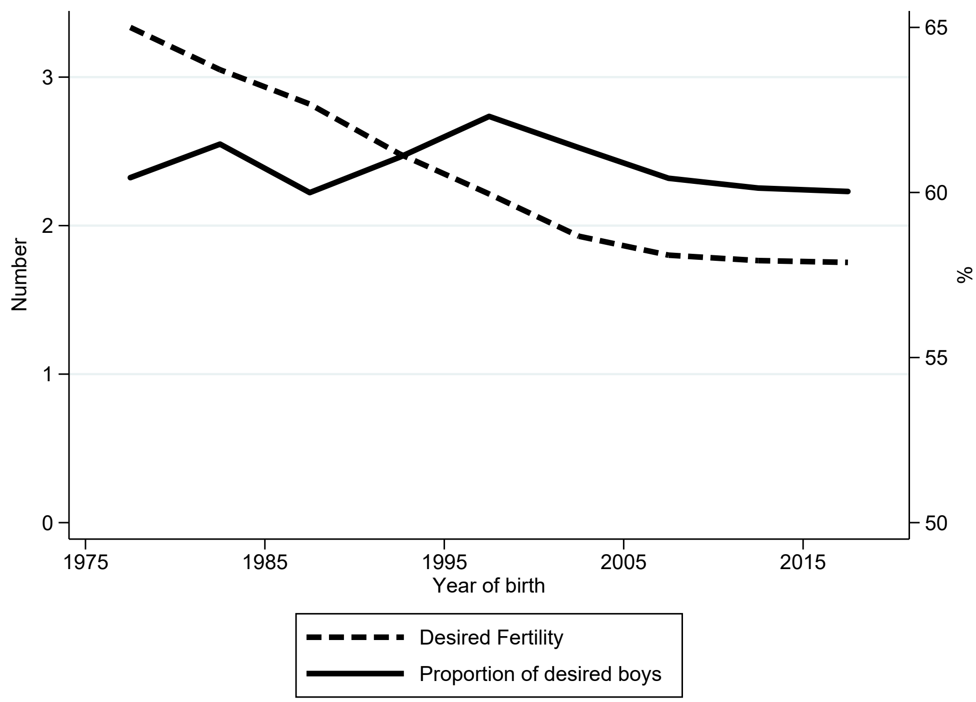
We now replicate our approach to estimate the share of instrumental and missing children for all countries

[32] The value of p used in these computations corresponds to the currently observed probability of a male birth across the population and takes into account the fact that some sex-selective abortions already took place. The value of $\bar{N}$ is chosen to be equal to the 90th percentile in the number of children observed in the country under analysis. Our results are essentially unaffected by the choice of this particular value as compared to the 80th, 95th or 99th percentiles.

[33] It is important to note that our approach is valid as long as sex-selective abortions are applied in the last ranks and simply replace the gender of the last born without affecting the actual number of births.

[34] See Appendix E for a list of the ratio used.

Figure 11: Desired fertility & Proportion of desired boys in India



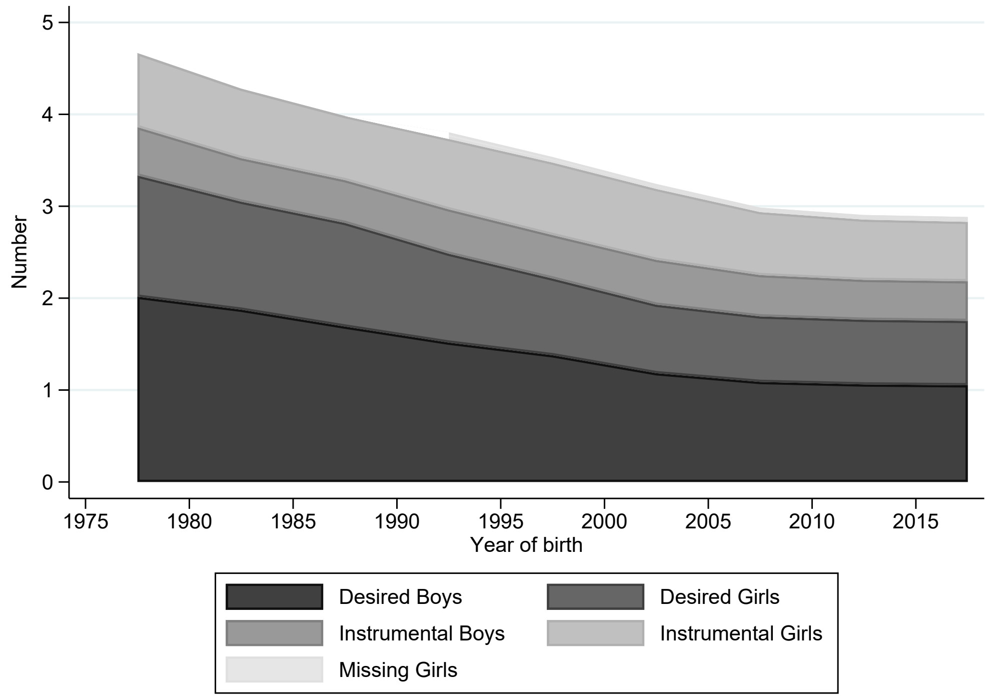
Data Source: DHS India 1993, 1999, 2006 and 2015.
Reading: Over the period 1995-2000, the total desired fertility is 2. The desired proportion of boys is 62%.

which we identify as applying the stopping rule. Using all births occurring after 2000, we identify 18 countries: Albania, Armenia, Bangladesh, Cameroon, Colombia, Comoros, DR Congo, Egypt, India, Jordan, Kenya, Nepal, Niger, Pakistan, Rwanda, Tajikistan, Turkey and Yemen. Table 1 reports the following indicators: the desired family size, the desired sex ratio,[35] the actual sex ratio, the proportion of instrumental boys among alive boys, the proportion of instrumental girls among alive girls, the share of instrumental children, the share of excess instrumental girls[36] and the share of missing girls at birth. The last column presents the prevalence of the stopping rule by summing the share of excess instrumental girls and that of missing girls at births. The prevalence of the stopping rule is the share of children directly affected by the stopping rule, either because they are instrumental or because they are born as a result of sex-selective abortions. Most of these countries display a strong bias in preferences for boys, with a desired sex ratio that varies between 109 (for Kenya) and 232 (for Armenia), and is particularly large in Asian countries as it never falls below 117 (in Pakistan), largely above the actual sex ratios.

[35] Defined as above as the ratio between the number of desired boys and the number of desired girls.

[36] Computed as the difference between the number of instrumental girls and the number of instrumental boys divided by the total number of children. Only the share of excess instrumental girls can be compared to that of missing girls at birth, since the latter is, strictly speaking, the net difference between the share of missing girls and the share of missing boys (which we cannot separately observe nor estimate given our approach).

Figure 12: Desired fertility, proportion of instrumental children and missings girls at birth in India



Data Source: DHS India 1993, 1999, 2006 and 2015.
Reading: Over the period 2010-2015, the number of missing girls is 0.05, that of instrumental boys 0.69 and of instrumental girls 1.02 on average per family.

Given this bias, the proportion of instrumental girls is systematically larger for girls than for boys. In Armenia, for instance, 64.5% of girls can be considered as instrumental, as against 25.3% of boys. In India, the corresponding figures are 53.4% and 34.2% for girls and boys respectively. Overall, the proportion of instrumental children hovers around 30%, with a proportion of instrumental girls close to twice as large as that of boys. On the other hand, 5 countries, Colombia, Cameroon, Comoros, Niger and DR Congo display a bias in preferences towards girls. The prevalence of the stopping rule is very diverse, with up to 21.8% children affected in Armenia and as compared to 1.6% in Kenya or 0% in Colombia.[37] Decomposing the stopping rule between its instrumental births and missing births components underlines the overall predominance of instrumental births.

The proportion of missing girls at birth, which we can only estimate for countries identified as practicing sex-selective abortion in the relevant sample, reaches 4.4% in Armenia, 1.7% in Albania, 3% in Tajikistan and 3.7% in India. The corresponding shares of excess instrumental girls are estimated at 17.4% for Armenia, 14.6% for Albania, 6.8 % in Tajikistan and 8.5% for India, largely exceeding missing girls. In other words, countries practicing the stopping rule overwhelmingly practice instrumental births only. In the countries in

[37]Our test detects Colombia as practicing the stopping rule. However the difference in the number of younger siblings between girls and boys, while significant, is small enough so that our model does not detect biased preferences.

which both instrumental births and sex-selective abortion is practiced, the latter is at lower magnitude compared to instrumental births. For stopping rule countries taken as a whole, stopping rule affects 9.1% of children, more than two third of which (6.4%) via instrumental births. Therefore, focusing on sex-selective abortion only, as is typically done in the literature, leads to an underestimation of more than 66% of the prevalence of the stopping rule.

Table 1: Preferences & Fertility

	Desired family size	Desired sex ratio	Actual sex ratio	Instrumental boys (%)	Instrumental girls (%)	Instrumental children(%)	Excess instrumental girls (%)	Missing girls (%)	Stopping Rule (%)
Armenia	1.26	232	112	25.26	64.44	43.9	17.42	4.35	21.77
Albania	1.38	207	101	25.95	59.95	42	14.61	1.73	16.34
Tajikistan	2.54	173	106	16.46	37.13	25.44	6.81	2.98	9.79
Jordan	2.74	169	102	21.98	44.48	32.21	8.23	0	8.23
Nepal	1.81	166	107	27.43	51.07	38.58	9.59	0	9.59
Rwanda	3.06	155	106	14.06	28.22	20.23	4.36	0	4.36
Egypt	2.2	153	105	23.85	42.27	32.38	6.77	0	6.77
India	1.64	148	110	34.17	53.36	43.52	8.49	3.74	12.24
Yemen	3.37	146	110	17.45	31.06	23.58	4.41	0	4.41
Bangladesh	1.76	123	107	28.47	37.51	32.83	3.36	0	3.36
Turkey	1.62	122	109	35.69	45.2	40.35	3.99	0	3.99
Pakistan	3.1	117	105	26.83	33.34	29.98	2.32	0	2.32
Kenya	2.34	109	100	35.33	39.32	37.3	1.59	0	1.59
Colombia	1	100	104	57.62	57.62	57.62	0	0	0
Cameroon	2.76	83	109	27.61	20.72	24	-2.26	0	2.26
Comoros	2.99	82	100	32.81	24.86	28.67	-2.78	0	2.78
Niger	3.87	80	103	19.57	13.47	16.29	-1.81	0	1.81
DR Congo	3.59	77	103	25.87	17.09	21.15	-2.77	0	0
Total	1.94	138	108	32.27	47.04	39.4	6.62	2.42	9.17

We end this empirical investigation by focussing on the case of India more finely, distinguishing between states and castes. We first replicate our approach over the 17 largest states of India, for all births occuring after 2000. Table 2 reports the same indicators as above for each state, which we rank by decreasing order of the desired sex ratio. As widely documented in the literature (following Sen (1990)), we observe a strong divide in gender preferences between North-Western and Southern states. Thus, the desired sex ratio is as high as 246% in Gujarat, 243% in Haryana or 202% in Punjab, but falls down to 123% in Tamil Nadu or 129% in Andra Pradesh. (The actual sex ratio follows closely this ranking, from the exceptionnally high 125% and 119% in Haryana and Punjab to around 106% in Southern States.) Thus, in Gujarat and Haryana, for each desired girl, parents desire almost 2.5 boys. These strong biases in the desired sex ratios in the North imply a very large proportion of instrumental girls: 58.3% of girls are instrumental in Haryana, as compared to 19.1% of the boys. By contrast, in regions in which the desired sex ratio is more balanced, the share of instrumental girls and boys are much closer: in Andhra Pradesh, for instance, these two shares are much closer from one another.

In the Southern states, the practice of sex-selective abortion is undetected in Karnataka, Goa and Odisha, and remains relatively negligible in other States. By contrast, self-selective abortion is widely practiced in the Northern States of Haryana and Punjab, where the shares of missing girls are as high as 6.9% and 5.7%. The share of missing girls in the Northern States fluctuates around 4%. This being said, the excess instrumental girl share remains largely above those figures, indicating again that, in the implementation of the stopping rule, the

Table 2: Preferences & Fertility across Indian States and Castes

	Desired family size	Desired sex ratio	Actual sex ratio	Instrumental boys (%)	Instrumental girls (%)	Instrumental children(%)	Excess instrumental girls (%)	Missing girls (%)	Stopping Rule (%)
					States				
Gujarat	1.66	246	114	20.18	60.43	38.32	16.16	4.74	20.9
Haryana	1.68	243	125	19.14	58.27	36.5	15.21	6.87	22.08
Punjab	1.36	202	119	27.36	60.63	43.23	14.62	5.65	20.27
Himachal Pradesh	1.26	200	106	31.48	64.76	47.89	15.96	2.92	18.88
Madhya Pradesh	1.84	197	106	23.88	54.85	38.17	12.45	2.94	15.39
Bihar	2.41	180	107	19.09	43.39	29.84	8.54	3.19	11.74
Maharashtra	1.42	168	114	31.04	55.94	43.05	10.91	4.77	15.68
Odisha	1.67	165	107	26.02	48.94	36.73	9.02	0	9.02
Rajasthan	1.85	164	114	29.03	52.47	40.19	9.78	4.69	14.47
Uttar Pradesh	2.72	157	112	14.08	28.67	20.42	4.51	4.11	8.62
Goa	1.03	151	107	39.11	59.49	49.27	10.05	0	10.05
Karnataka	1.25	150	106	38.26	58.24	48.18	9.64	0	9.64
West Bengal	1.02	149	108	45.22	64.63	55.12	10.81	0	10.81
Assam	1.94	140	106	23.81	37.81	30.36	5.01	0	5.01
Andhra Pradesh	1.6	129	106	25.37	35.98	30.41	3.8	2.92	6.72
Tamil Nadu	1.25	123	109	36.98	47.11	41.96	4.36	3.45	7.81
Kerala	2.07	105	105	0	0	0	0	0	0
					Castes				
High Castes	1.42	246	114	21.59	62.55	40.41	17.07	4.64	21.72
Other Backward Caste	1.83	186	111	22.53	50.14	35.1	10.55	4.07	14.62
Scheduled Tribe	1.9	175	106	26.54	52.63	38.78	10.61	2.83	13.44
Muslims	2.29	160	108	24.62	45.61	34.36	7.95	0	7.95
Scheduled Caste	1.82	156	109	30.43	51.67	40.61	8.92	3.44	12.36

practice of instrumental births remains preponderant. For instance, excess instrumental girls represent 15.2% of children in Haryana while the share of missing girls is order of magnitude lower, at 6.9%. That is, in Haryana, 22.1% of children are affected by the stopping rule, but focusing on sex-selective abortion alones leads to an understimation of more than two third of the prevalence of the stopping rule.

We report in the lower panel of the Table a similar exercise distinguishing between five social groups: the High Castes[38], the Other Backward Castes, the Scheduled Castes, the Scheduled Tribes and the Muslims.[39] There again, our estimates follow the established Caste hierarchy, which matches closely the observation that gender biased preferences are stronger among higher castes (Chakravarti, 1993; Kapadia, 1997; Field et al., 2010; Luke and Munshi, 2011; Cassan and Vandewalle, 2021). Thus, the desired sex ratio is on average equal to 246% among high castes but falls to 140% among Muslims. The share of missing girls ranges from 4.7% among High Castes to 0% among Muslims, much inferior to the share of instrumental births.

4 Comparison with other approaches

4.1 The sex ratio of the last born

In the literature, the most popular measure of instrumental births is based on a literal interpretation of the stopping rule: the last born in the family tends to be a boy. As a result, countries in which the stopping rule is prevalent should display a large proportion of sons among the last born. This proportion is then simply compared

[38]Defined here as all individuals non belonging to the other categories.

[39]The Muslim category includes Muslims classified as Other Backward Classes, our Other Backward Classes category therefore only contains non Muslim individuals.

to a counterfactual sex ratio, typically the "natural" sex ratio. While intuitive, this approach suffers from some important shortcomings. First and foremost, there is no universal natural sex ratio at birth: depending on the ethnic group and the period considered, it can vary between 103 and 107 boys per 100 girls (see for instance Chahnazarian (1988); Waldron (1998) and the discussion in Anderson and Ray (2010)). Sex ratio at births also vary with environmental factors, nutritional status or paternal age, so that, even within the same ethnic group at a particular time period, one cannot rely on a well-defined benchmark (see, for instance, Bruckner et al. (2010) and Catalano and Bruckner (2005)).[40] The existence of such a benchmark is made even more elusive in the presence of sex-selective abortion.[41]

Second, by focussing on the gender of the last born, this approach naturally applies to families with completed fertility. As a result, this measure necessarily describes the behavior of older cohorts of mothers. By contrast, through our test, the difference in the number of younger siblings emerges as soon as families have reached a number of births exceeding their desired number of boys or girls, largely before completing fertility. Moreover, this difference can be detected at each rank, so that a test carried out at the level of the eldest child is already informative (particularly in the event of sex-selective abortion at late ranks). Our measure can therefore detect behavioral changes much sooner than measures relying on the sex ratio of the last born.

We now compare the relative performance of our test to that based on the sex ratio of the last born. As explained above, the latter requires a natural sex ratio to be used as a reference. Given the uncertainty surrounding its precise value, we run the test for two plausible values of this ratio, 103 and 107.[42] In Figure 13 below, we compare the value obtained under our measure (on the vertical axis) to the corresponding value of the sex ratio of the last born (on the horizontal axis). Each dot in the graph corresponds to a particular country (the corresponding confidence intervals are not reported for the sake of exposition). The two measures are, as expected, reasonably correlated.

The Figure illustrates the poor performance of methods based on the sex ratio of the last born. It is for 71% of the countries (the white dots) that the observed sex ratios, given their confidence intervals, lead to conclusions that do not depend on the value chosen as a reference (103 or 107). (Our test agrees with 84% of them.) By contrast, for the other countries (the black dots), the conclusion is ambiguous. We report these cases with their corresponding confidence intervals in Figure 14 below. According to our test, the stopping rule prevails in half of them (which we represent by black triangles or squares).[43] Thus, Kyrgyzstan, Morocco and Kenya, for instance, apply the stopping rule against girls according to our test, but fail to be detected by the

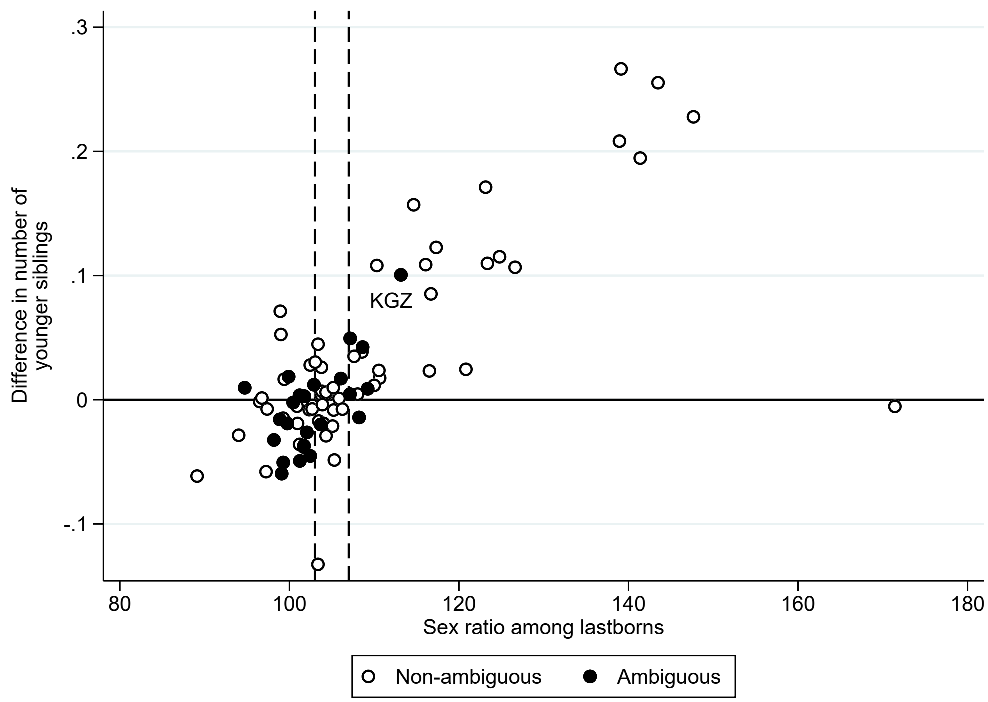
[40] For instance, Catalano et al. (2008) show that women under colder weather abort more male foetuses, so that a 1° C increase in annual temperature predicts one more male per 1,000 females born in a year. In a similar vein, Helle et al. (2009) in their analysis of sex ratios between 1865 and 2003 showed a strong increase of excess male births during periods of exogenous stress, such as World War II.

[41] Additionnally, the use of survey data makes the estimates particularly noisy: thus, for an observed sex ratio of 105, the 95 percent confidence interval ranges between 100.8 and 109.2 in a sample of 10,000 births.

[42] Clearly, the comparison is even less favourable to the sex ratio of the last born for more extreme, but plausible, values of the benchmark.

[43] As stressed above, our test provides a sufficient condition for instrumental births and may thus leave a number of situations undetected.

Figure 13: Our test of instrumental births against the sex ratio of the lastborn



Data Source: All DHS
Reading: In Kyrgyzstan, girls have 0.1 more younger siblings than boys and the sex ratio of the lastborn is 113. However, the sex ratio of the lastborn is not statistically different from both 103 and 107 and does not allow to conclude that instrumental births are used.

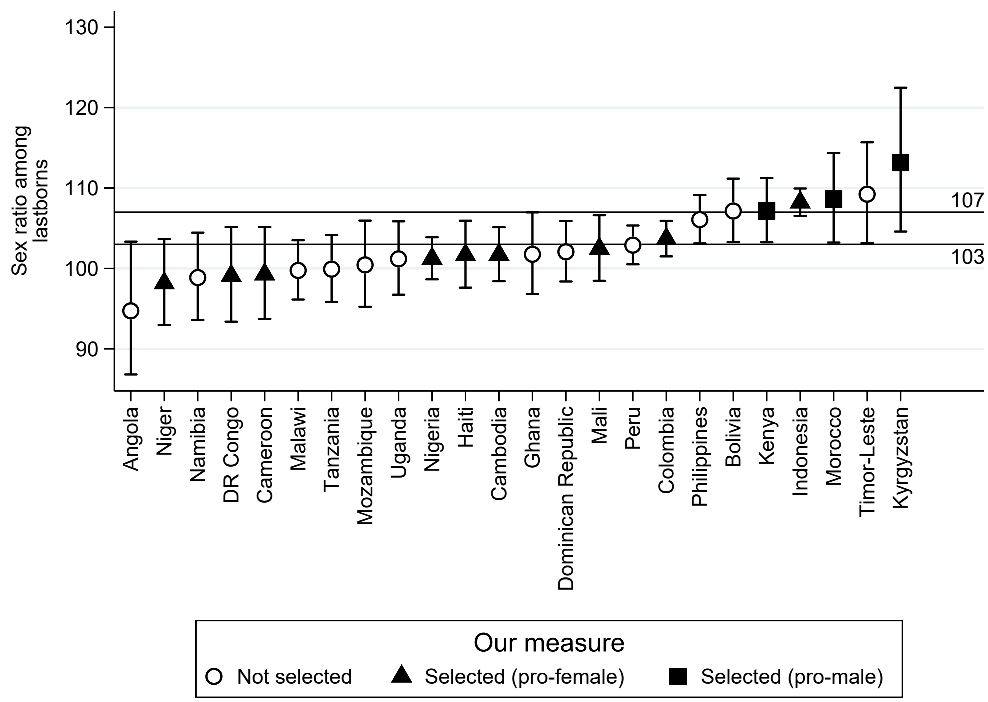
sex ratio of the last born when a cut-off ratio of 107 is used.

4.2 Other popular measures

Another method used in demography is the "parity progression ratio" (Ben-Porath and Welch, 1976; Williamson, 1976; Arnold, 1997; Arnold et al., 1998; Norling, 2015). It evaluates, at a given birth rank, the relative probability to continue childbearing (the opposite of being the last born) given the gender of the child at that rank. This measure, while close to the "sex ratio of the last born", is particularly relevant here as it does not rely on a natural sex ratio at birth. It however suffers from a number of limitations. First, it is a rank-specific measure, with no clear interpretation when the measure gives conflicting results at different ranks.[44] Relatedly, given that it is based on a ratio of two probabilities, the literature does not provide a clear way to aggregate it over ranks. One possibility could be to estimate, over all ranks, the difference (instead of the ratio) between boys

[44]For example, Filmer et al. (2009)'s find evidence of instrumental births as detected with parity progression for families of size 3, but not for families of sizes 2 and 4 in Sub Saharan Africa. They write "it is difficult to take in all of the coefficients at a glance." In addition, given the complexity of the approach, they restrict their analysis to comparing families not having any sons at given rank to families not having any daughter, therefore omitting from the analysis all intermediate cases.

Figure 14: Added precision of our instrumental births test compared to the sex ratio of the lastborn



Data Source: All DHS data of countries considered as ambiguous in Figure 13.
Reading: In Kyrgizstan, the sex ratio of the last born is 113, but is not statistically different from 107. Our test allows to unambiguously classify Kyrgizstan as practicing instrumental births.

and girls in their probability of having a younger sibling. This difference however corresponds essentially to the sex ratio of the last born, and uses exactly the same information. In this respect, our measure generalizes this approach by counting the number of younger siblings obtained and thereby better exploiting the information available. The parity progression ratio, because of its focus on the next pregnancy, is less efficient.

Second, children of all ranks below the 'desired number of boys or girls' necessarily have younger siblings, irrespective of their gender. Thus, if parents want, for instance, at least 2 boys, the first born of the family will necessarily have a younger sibling. It is only at later ranks that the parity progression ratio can detect a stopping rule behavior. This is problematic for comparative studies, as the desired number of sons and daughters may vary across countries and over time and would require to vary the rank analyzed across countries according to their desired number of boys and girls.

One may also think of using birth-spacing as a measure of instrumental births, following the idea that parents with a strong preference for sons will reduce the time between a new-born girl and her next sibling (see Jayachandran (2015); Rossi and Rouanet (2015)). One can then compare the average birth spacing of a girl compared to a boy, possibly aggregated over all ranks. Under this approach, the only reason why parents would want to selectively reduce birth spacing is because they want more younger siblings when the new born is a girl. However, the reduction of birth spacing is not a necessary step to do so. Therefore, while the detection of a gender difference in birth spacing implies the practice of instrumental births, the opposite is not true. Moreover, birth spacing is a particularly noisy observation, given the uncertainty associated with pregnancies. Finally, since sex-selective abortion affects birth spacing, this measure becomes less relevant when sex-selective abortion becomes widespread (Dimri et al., 2019).

A last set of measures proposed in the literature is based on the consequences of the stopping rule. According to Basu and de Jong (2010), girls tend to be born in larger families and to have, within families, earlier ranks than boys (see also Yamaguchi (1989)). However, as shown in Section 2, girls do not face larger families at birth. It is only after their birth that their families grow larger under the stopping rule. This also explains why, within families, girls are born at earlier rank than boys on average. The measure we propose follows the same intuition but is more direct and precise. Following the idea behind the parity progression ratio, Arnold (1985) proposes to compare the declared use of contraceptives depending on the gender composition of the family. Being based on current use, this method is less sensitive to recall biases, but may suffer from report biases as it relies on sensitive information. It also crucially hinges upon the availability of contraceptives.

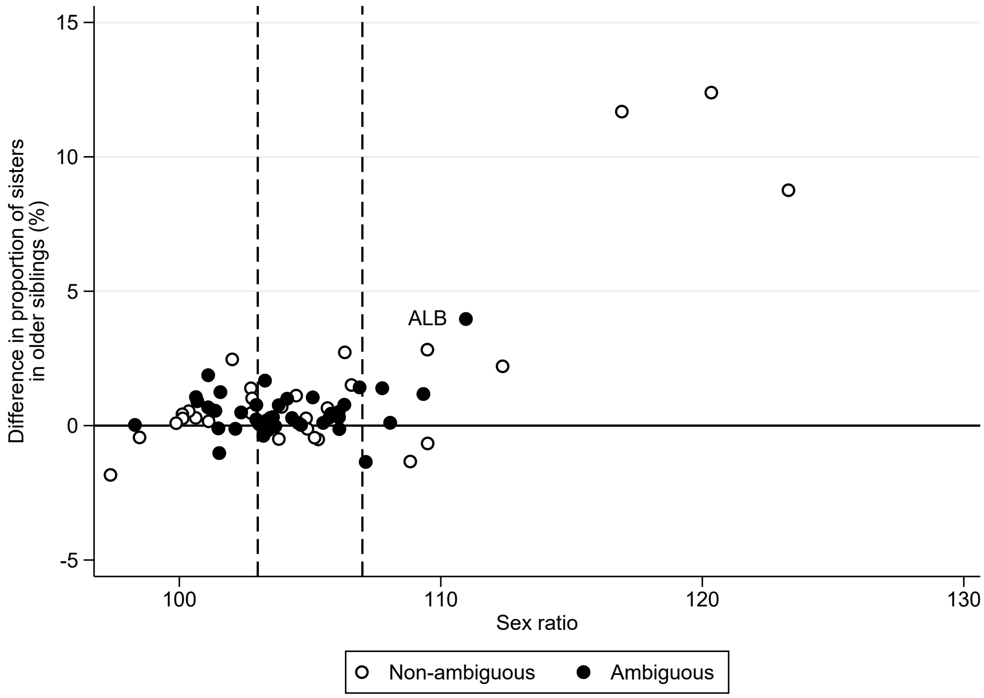
4.3 The sex ratio and sex-selective abortions

The theoretical literature on sex-selective abortion is less abundant. In fact, the literature mostly focused on detecting its occurrence following the introduction of the ultra-sound technology. The dominant approach rests on a comparison between the actual and the natural sex ratio in a given population. More sophisticated methods rely on the idea that sex-selective abortion is less prevalent in first ranks. This literature typically follows a difference-in-difference approach by comparing sex ratios at birth across ranks and over time, for countries such as Taiwan (Lin et al., 2014), South Korea (Park and Cho, 1995), China (Zeng et al., 1993; Chen et al., 2013), India (Bhalotra and Cochrane, 2010; Jayachandran, 2017; Anukriti et al., 2022) or the United States (Abrevaya, 2009). Our approach of sex-selective abortion gives a theoretical foundation to these empirical studies, while allowing for a measure that is not rank-based and is, therefore, better suited for comparative approaches.

As above, we now assess the relative performance of our test to that of the traditional approach, which compares the observed proportion of boys in the population to the natural sex ratio (which, as above, we assume to be either 103 or 107). Figure 15 reports the value obtained under our measure (on the vertical axis) and the corresponding value of the observed sex ratio (on the horizontal axis).

The white dots represent countries for which a simple comparison of sex ratios leads to conclusions that do not depend on the value of the cut-off (103 or 107). They barely represent 43% of the countries (our measure agrees with 69% of these conclusions). Conversely, the black dots represent all these countries for which the choice of the benchmark leads to conflicting conclusions about the prevalence of sex-selective abortion. These

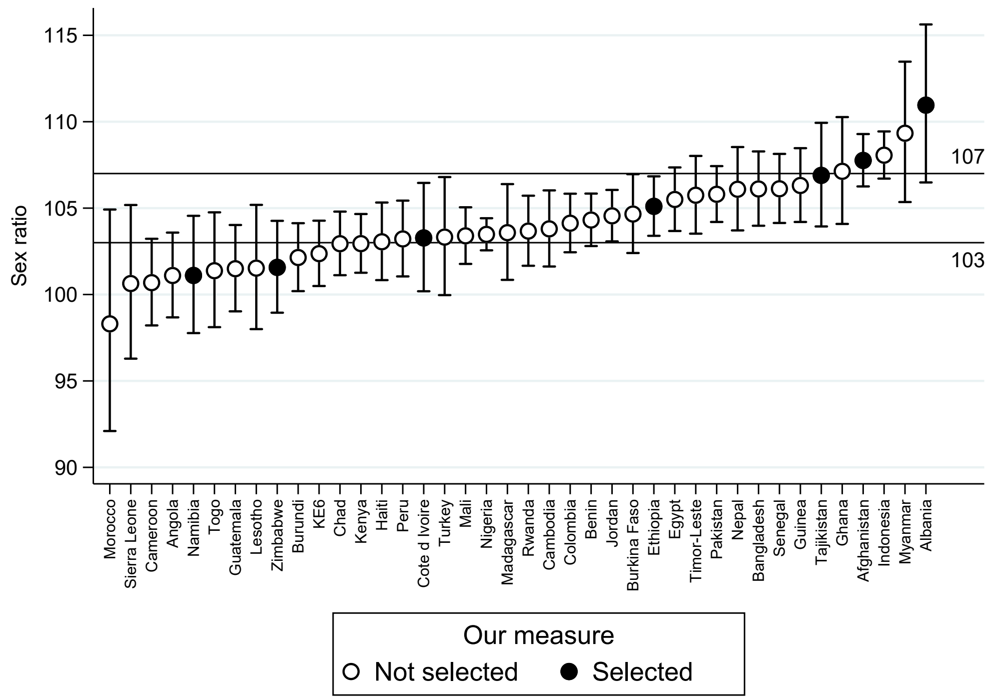
Figure 15: Our test of detection of sex-selective abortion against the sex ratio at birth



Data Source: All DHS, births taking place after 2000.
Reading: In Albania, boys have 3.97 percentage points more girls in their elder siblings than girls and the sex ratio at bith is 111. However, the sex ratio at birth is not statistically different from both 103 and 107 and does not allow to conclude that sex-selective abortions are used.

ambiguous cases represent the remaining 57% of our sample. In Figure 16, we report for these countries a classical mean test using the observed sex ratio with the corresponding 95% confidence intervals. Among these, 7 countries (18 %) are identified by our test as practicing sex-selective abortion (as indicated by the black dots). This is the case, for instance, of Albania or Afghanistan for which the traditional approach remains inconclusive with a benchmark of 107.

Figure 16: Added precision of our test of sex-selective abortion compared to the observed sex ratio



Data Source: All DHS (births taking place after 2000) of countries considered as ambiguous in Figure 15.
Reading: In Albania, the sex ratio at birth is 111, but is not statistically different from 107. Our test allows to unambiguously classify Albania as practicing sex-selective abortions.

5 Conclusion

The stopping rule refers to this behaviour by which parents continue child bearing until they reach a specific number of children of a given gender. Parents can then choose to carry out these pregnancies to term, leading to a larger number of children than originally desired, a practice defined as instrumental births. They can also choose to abort foetuses of a specific gender, a practice known as sex-selective abortion. While these two practices have been investigated independently in the literature, they are closely related as they both result from the same fundamental behaviour. We propose a unified framework to consider them jointly. This framework underlines the policy trade off implied by the substituability of the two practices.

Were pregnancies directly observable, these two practices could be measured in a straightforward manner. The literature provides different indirect methods aimed at estimating the consequences of these practices, which suffer from important shortcomings. Taking the child as the unit of interest, we propose, with the help of a simple model, new measures to detect these two practices. Under instrumental births, a girl is, on average, exposed to a larger number of younger siblings than a boy. Under sex-selective abortion, a girls also has on average more elder brothers than a boy. Unlike the existing measures proposed in the literature, our measures do not require the use of a counterfactual benchmark. They can be easily implemented, are defined at the level of the child and do not require a completed fertility. They are also more efficient as they make use of all the information available given the current demographic composition of the family.

We implement our detection tests over a large set of countries, and quantify, for the countries identified by our tests, the magnitude of gender bias in parental preferences. Calibrating a simple model of gender biased preferences, we show that the desired sex ratio exceeds 130 boys for 100 girls in countries such as India, Armenia and Nepal, largely above the actual sex ratios. Overall in the countries in which stopping rule is being practiced, instrumental births represent more than two third of the stopping rule. Studying instrumental births independently of sex-selective abortions can therefore lead to very large underestimation of the prevalence of the stopping rule.

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Appendix

A Proof of Proposition 1

Let us first assume that the child at rank k is a boy and consider his younger siblings. Three cases arise. In a first case, the desired number of boys is obtained before reaching the maximal number of children, which occur with probability $\sum_{j=1}^{\bar{N}-k-1} B\left(b^{*}-e-1, j\right)$ (where $B\left(a, b\right)$ is the simple binomial probability of having exactly a successes in b trials). In the second case, one needs exactly $\bar{N}$ children to reach the desired number of boys, b^{*}. This occurs with probability $\left(p \sum_{j=1}^{\bar{N}-k-1} B\left(b^{*}-e-2, j\right)\right)$: with their $\bar{N}-1$ younger children, the parents have exactly $n^{*}-1$ boys and, with probability p, their last child, at rank $\bar{N}$, is a boy. Finally, one finds parents who do not reach their desired number of boys when having $\bar{N}$ children.

Consider now a girl of the same rank k who has e older brothers. Suppose first that her next sibling is a boy. For all families that reach their desired number of boys with less than $\bar{N}$ children, this boy will have exactly the same expected number of younger siblings to that of a boy of rank k who has e older brothers. For families which, with a boy at rank k, reach a size $\bar{N}$, his expected number of younger siblings is equal to the expected number of younger siblings of a boy of rank k minus 1. In other words, the expected number of siblings of this boy of rank $k+1$, which we denote by $E\left(Y_{b}\left(k+1, e\right) \mid g_{k}\right)$ (to indicate that her sibling of rank k is a girl, g), is given by:

$$E\left(Y_{b}\left(k+1, e\right) \mid g_{k}\right)=E\left(Y_{b}\left(k, e\right)\right)\left(\sum_{j=1}^{\bar{N}-k-1} B\left(b^{*}-e-1, j\right)\right)+\left(E\left(Y_{b}\left(k, e\right)\right)-1\right)\left(1-\sum_{j=1}^{\bar{N}-k-1} B\left(b^{*}-e-1, j\right)\right)$$

$$\Longleftrightarrow E\left(Y_{b}\left(k+1, e\right) \mid g_{k}\right)=E\left(Y_{b}\left(k, e\right)\right)-1+\left(\sum_{j=1}^{\bar{N}-k-1} B\left(b^{*}-e-1, j\right)\right).$$

Suppose instead that her next sibling is a girl. Following the same reasoning as above, this girl, of rank $k+1$, has an expected number of younger siblings which is given by:

$$E\left(Y_{g}\left(k+1, e\right) \mid g_{k}\right)=E\left(Y_{g}\left(k, e\right)\right)-1+\left(\sum_{j=1}^{\bar{N}-k-1} B\left(b^{*}-e, j\right)\right).$$

As a result, the expected number of younger siblings for a girl of rank k with e older brothers, $E\left(Y_{g}\left(k, e\right)\right)$,is given by 1 plus expectation of the number of younger siblings of that girl's next sibling:

$$E\left(Y_{g}\left(k, e\right)\right)=1+pE\left(Y_{b}\left(k+1, e\right) \mid g_{k}\right)+(1-p)E\left(Y_{g}\left(k+1, e\right) \mid g_{k}\right)$$

$$= 1 + p\left(E\left(Y_b\left(k,e\right)\right) - 1 + \left(\sum_{j=1}^{\bar{N}-k-1} B\left(b^* - e - 1, j\right)\right)\right) + (1-p)\left(E\left(Y_g\left(k,e\right)\right) - 1 + \left(\sum_{j=1}^{\bar{N}-k-1} B\left(b^* - e, j\right)\right)\right)$$

$$= E\left(Y_b\left(k,e\right)\right) + \left(\sum_{j=1}^{\bar{N}-k-1} B\left(b^* - e - 1, j\right)\right) + \frac{1-p}{p}\left(\sum_{j=1}^{\bar{N}-k-1} B\left(b^* - e, j\right)\right)$$

$$\Longrightarrow E\left(Y_g\left(k,e\right)\right) > E\left(Y_b\left(k,e\right)\right),\ \forall k < \bar{N}, e \leq b^* - 1.$$

□

B The stopping rule with a desired family size

The literature sometimes uses a slightly different approach than the one we follow (see Sheps (1963), for example). While they still assume that parents desire a given number of boys, b^*, parents also have a preference over their total number of children, n^*, which corresponds to their ideal family size. If, with n^* children, they do not have b^* boys, they continue to have children till they reach their desired number of boys. In other words, these parents have lexicographic preferences in n^* and b^*, with $0 < b^* \leq n^*$. To analyze this alternative model, we first assume away a constraint on the maximum number of children so that parents, if needed, have as many children as they need to reach the desired number of boys.

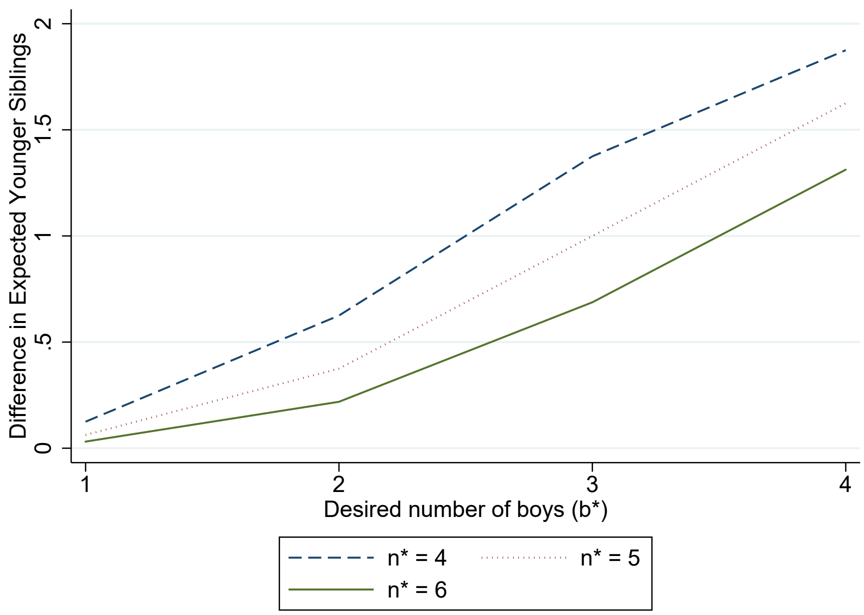
Consider first a family that succeeds in having at least b^* boys with n^*children. In such families, at any rank k, girls and boys have exactly the same number of younger siblings, which is equal to $(n^* - k)$. The proportion of such families in a large population is equal to the probability of having at least b^* 'successes' (boys) in n^* trials (children), which we denote as above $\sum_{j=b^*}^{n^*} B\left(j, n^*\right)$. All other families need more than n^*children to reach their desired number of boys. In such families, at any rank k, a girl will have $1/p$ more younger siblings than a boy, $1/p$ corresponding to the expected number of children necessary to have one extra boy. The proportion of such families is given by $\sum_{j=0}^{b^*-1} B\left(j, n^*\right)$. We therefore have:

Proposition 3: In families with lexicographic preferences over (b^*, n^*), at any rank, girls have in expected terms $\left(\frac{1}{p}\sum_{j=0}^{b^*-1} B\left(j, n^*\right)\right)$ more younger siblings than boys of the same rank.

A direct consequence of this proposition is that a girl on average (i.e., over all ranks) will also have $\left(\frac{1}{p}\sum_{j=0}^{b^*-1} B\left(j, n^*\right)\right)$ more younger siblings than a boy. A closer examination of this expression is illustrated in Figure 17: the difference in the expected number of younger siblings is larger for a smaller desired family size and for a larger desired number of boys. Note for example how, for a given desired number of boys an increase in the ideal family size leads to a decrease in the difference in younger siblings (a change in curve). Note also how, for a given ideal family size, an increase in the number of desired boys increases the difference in younger siblings (a change along the curve). As a result, it is likely that societies undergoing a demographic transition display a stronger differential in younger siblings than societies characterized by larger family sizes, provided the desired number of boys does not vary too much. That is, the fertility squeeze hypothesis (Guilmoto, 2009; Jayachandran, 2017) not only applies to sex-selective abortions but also to instrumental births.

Finally, imposing a constraint on family sizes in this setting does not change our main results. Assume again that family size cannot exceed a given level $\bar{N}$. Clearly, this constraint is only binding for families that needed more than n^* children to have their desired number of boys, b^*. Among this subset however, Proposition 1 above applies. More precisely, at any rank $k > n^*$,with $n^* < k < \bar{N}$ and for any number of elder brothers e, with $e \leq b^* - 1$, the expected number of younger siblings is strictly larger for a girl than for a boy.

Figure 17: Difference in expected number of younger siblings between girls and boys with lexicographic preferences in b^*



Data Source: Author's simulations.
Reading: When parents have an ideal number of boys b^* of 2, and an ideal family size n^* of 4, girls one average have 0.625 more younger siblings than boys. When parents want the same number of boys but for an ideal family size n^* of 6, girls have on average 0.219 more younger siblings than boys.

C Imperfect household information

Because our tests take the perspective of a child and his elder and younger siblings, the ideal dataset to perform our tests is fertility history. However, information on the complete fertility history is not always present in standard household surveys, for instance when the only source of information comes from a household roster. We now discuss the performance of our tests in this setting. A household roster lists the gender, age and family linkage of household members living in the household, excluding children no longer living in this household. A child missing from the household roster has two implications: our measures are not computed for this child (a selection issue) and this child is not accounted for when computing our measures on her siblings (a measurement issue).

As long as the probability of leaving the household is uncorrelated with gender, our tests remain unbiased but are simply less precise. However, in gender biased societies, the presence of a child in a household is correlated with gender, for instance because the age at marriage differs across gender. Consider first the case in which (i) children leave the household upon marriage and (ii) girls marry at a younger age than boys.[45] As a result, relatively older girls are not accounted for when aplying our measures on their siblings. This is also true for older boys, but to a lower extent, given that they leave the household at a later age.

Consider first the detection of instrumental births. Because older boys and girls are unobserved, the average number of younger siblings is biased downwards for both genders (as we apply our measure on younger siblings who, by definition, have less younger siblings than their elder, unobserved, brothers and sisters). However, since more elder girls go unobserved (relative to boys), the selection bias is more pronounced for girls and the difference in younger siblings between girls and boys is downwards biased. In terms of measurement bias, because the unobserved children are the elder, their absence does not affect our measure for younger children (i.e. the number of younger siblings of these younger children). The only situation in which our measure is affected is for relatively older boys, who are too young to be themselves married, but whose younger sisters are already married. For these boys, the number of younger siblings we measure is lower than the actual one, which biases upwards the difference in younger siblings between girls and boys. It turns out that, in the numerous simulations we ran, this measurement bias is much less important than the selection bias discussed above. As a result, our test, applied to household rosters, underestimates instrumental births. That is, the bias implied by the use of our test for instrumental births typically do not lead to falsely conclude that they are practiced while they are not (false positive). However, the opposite is true: in presence of such bias, our test can be falsely negative.

We now discuss the detection of sex-selective abortion in this context. As discussed in the main text, under

[45] Patrilocality, whereby boys do not leave their parents while girls, once married, do, reinforces this bias. In comparison, differential mortality rates among older children are of much lower importance, but our discussion easily extends to this issue as well.

sex-selective abortion, the proportion of girls among older siblings is larger for boys than for girls, and this difference gets larger at later ranks. Since the missing observations in household rosters are older children for which this difference is less important, our measure applied to the observed, later rank, children is upwards biased. In terms of measurement bias, the discussion is more intricate. In general, since more elder girls than boys are missing, the proportion of girls among elder siblings is lower than the actual one. But this underestimation is symmetric across gender and does not, per se, create a bias. The asymmetry is again located in this age interval in which girls tend to be married while boys remain in the household. In the interval, the fact that girls are more often missing does not affect their older brothers, but only their younger brothers or sisters. (For the latter, the proportion of girls among elder siblings we measure is lower and the proportion of boys higher, than the actual ones.) Since boys are more numerous in the interval, and are therefore less often impacted by the disappearance of their younger sisters, the measure is, on average, less biased for boys than for girls. The measurement bias tends therefore to also overestimate the difference in the proportion of girls among elder siblings between boys and girls. In general, household roster surveys overestimate our measure for sex-selective abortion. That is, in presence of such bias, our test for sex-selective abortion may lead to more false positive and less false negative.

Finally, let us consider a survey which only provides the number and the gender composition of children in a household. Absent birth ranks, we cannot reconstruct the number of younger siblings or the gender of older siblings of a particular child. In terms of instrumental births, we can still follow Equation 3 and replace the number of younger silbings by the total number of siblings, essentially testing whether girls, on average, live in larger families. While, under gender biased preferences, girls have more younger siblings, which will mechanically translate into a larger number of siblings, girls are also, on average, of lower birth rank, and therefore have fewer older siblings than boys. The latter effect never dominates, and, for large enough sample size, a test based on family size, while less precise, will yield the same outcome as the one proposed in this paper.

D List of DHS surveys

Table 3 lists all the DHS surveys used as well as their number of observations.

Table 3: List of DHS surveys

	Year of interview	Observations
Afghanistan	2015	125715
Albania	2009	12766
.	2017	16128

Angola	2015	42002
Armenia	2000	11286
.	2005	10297
.	2010	8424
.	2016	8771
Azerbaijan	2006	13565
Bangladesh	1994	32590
.	1996	29366
.	2000	31925
.	2007	30527
.	2011	45844
.	2014	43772
Benin	1996	19359
.	2001	19398
.	2006	57232
.	2012	47152
.	2017	45853
Bolivia	1989	22338
.	1994	24174
.	1998	29473
.	2003	45116
.	2008	40355
Brazil	1986	12356
.	1991	15363
.	1996	25513
Burkina Faso	1993	20655
.	1999	22145
.	2003	41520
.	2010	56178
Burundi	1987	11886
.	2010	24520
.	2016	45419
Cambodia	2000	40990

.	2005	40457
.	2010	37511
.	2014	33290
Cameroon	1998	15187
.	2004	29455
.	2011	42312
Central Africa	1994	16936
Chad	1997	25739
.	2004	21448
.	2015	68989
China	1991	7519
.	1993	7421
.	2000	8720
.	2004	8551
.	2006	8952
.	2009	8949
.	2011	9657
.	2015	4064
Colombia	1986	11622
.	1990	15976
.	1995	21830
.	2000	21267
.	2005	71278
.	2010	91399
.	2015	62593
Comoros	1996	7913
.	2012	11497
Congo	2005	16687
Cote d Ivoire	1994	24870
.	1999	7575
.	2005	13358
.	2012	28211
DR Congo	2007	29548

.	2013	59276
Dominican Republic	1986	20151
.	1991	17168
.	1996	19784
.	1999	2871
.	2007	58037
.	2013	18167
Ecuador	1987	11835
Egypt	1988	35519
.	1992	38076
.	1995	56381
.	2000	54780
.	2005	61455
.	2008	48619
.	2014	59266
El Salvador	1985	6381
Ethiopia	1992	44174
.	1997	39881
.	2003	45540
.	2008	41392
Gabon	2000	16878
.	2012	23109
Gambia	2013	26601
Ghana	1988	14216
.	1993	13298
.	1998	13188
.	2003	15086
.	2008	11888
.	2014	23118
Guatemala	1987	14698
.	1995	38753
.	1999	18581
.	2015	55398

Guinea	1999	22943
.	2005	27115
.	2012	27683
.	2018	28887
Guyana	2005	4923
Haiti	1994	12547
.	2000	26437
.	2006	24830
.	2012	29013
.	2017	27809
Honduras	2006	50093
India	1993	275172
.	1999	268879
.	2006	256782
.	2015	1315617
Indonesia	1987	39719
.	1991	74329
.	1994	90326
.	1997	86276
.	2002	79791
.	2007	84726
.	2012	83650
.	2017	86265
Jordan	1990	32812
.	1997	24243
.	2002	25296
.	2007	43460
.	2009	38199
.	2012	42275
.	2017	47040
Kazakhstan	1999	8106
Kenya	1989	25173
.	1993	23899

.	1998	23351
.	2003	22074
.	2009	22534
.	2014	83591
Kyrgyzstan	1997	8781
.	2012	16180
Lesotho	2004	14708
.	2009	14429
.	2014	11710
Liberia	1986	17264
.	2007	22123
.	2013	30804
Madagascar	1992	18931
.	1997	21653
.	2004	20799
.	2009	48464
Malawi	1992	16330
.	2000	40421
.	2004	35883
.	2010	72301
.	2015	68074
Maldives	2009	20136
.	2017	13922
Mali	1987	12252
.	1996	37921
.	2001	48407
.	2006	52140
.	2012	33803
.	2018	33379
Mexico	1987	22676
Moldova	2005	9903
Morocco	1987	25518
.	1992	22657

.	2003	32494
Mozambique	1997	25752
.	2003	37443
.	2011	37984
Myanmar	2016	22989
Namibia	1992	13372
.	2000	14946
.	2007	19522
.	2013	18090
Nepal	1952	29156
.	2001	28955
.	2007	26394
.	2011	26615
.	2017	26028
Nicaragua	2001	34157
Niger	1992	23841
.	1998	28888
.	2006	34378
.	2012	44183
Nigeria	1990	28123
.	2003	23038
.	2008	104808
.	2013	119386
.	2018	127545
Pakistan	1991	27369
.	2006	39049
.	2012	50238
.	2018	50495
Paraguay	1990	15346
Peru	1986	13291
.	1991	38783
.	1996	72390
.	2000	65453

.	2007	89220
.	2012	47261
Philippines	1993	35863
.	1998	32626
.	2003	30443
.	2008	28518
.	2013	31680
.	2017	47244
Rwanda	1992	19440
.	2000	27602
.	2005	30072
.	2010	32639
.	2015	30058
Sao Tome	2008	7620
Senegal	1986	14389
.	1993	20815
.	1997	27448
.	2005	39895
.	2011	42510
.	2016	22740
Sierra Leone	2008	21136
South Africa	1998	22934
Sri Lanka	1987	17705
Sudan	1990	25805
Swaziland	2006	11410
Tajikistan	2012	19938
.	2017	21985
Tanzania	1991	29143
.	1996	24890
.	1999	11952
.	2004	30557
.	2010	29777
.	2015	37169

Thailand	1987	17796
Timor-Leste	2009	35998
.	2016	28682
Togo	1988	10782
.	1998	26269
.	2014	26264
Trinidad	1987	7837
Tunisia	1988	16463
Turkey	1993	19762
.	1998	17791
.	2004	22443
.	2008	19678
.	2013	17871
Uganda	1988	16074
.	1995	22752
.	2001	23410
.	2006	30090
.	2011	28609
.	2016	57906
Ukraine	2007	8007
Uzbekistan	1996	9650
Vietnam	2002	14383
Yemen	1991	29803
.	2013	64602
Zambia	1992	22122
.	1996	24799
.	2002	23805
.	2007	21366
.	2013	49207
Zimbabwe	1988	12405
.	1994	16777
.	1999	14184
.	2005	19489

.	2010	19279
.	2015	20791

E "Natural" sex ratios

Table 4 presents the average sex ratios estimated between 1950 and 1980 by Chao et al. (2019) that we use as reference "natural" sex ratio in our estimation of missing girls at birth.

Table 4: "Natural" sex ratios from Chao et al. (2019)

	Natural Sex Ratio
Albania	106.37
Armenia	106.26
Azerbaijan	106.24
Bangladesh	105.01
Cameroon	102.71
Colombia	104.73
Comoros	102.97
DR Congo	102.62
Egypt	106.29
Gabon	102.06
India	105.73
Jordan	106.56
Kenya	101.95
Kyrgyzstan	105.27
Nepal	104.82
Niger	104.02
Pakistan	106.24
Rwanda	102.33
Sierra Leone	103.3
Tajikistan	106.22
Turkey	104.69
Yemen	106.16