Stopping rule as sex-selective abortions and instrumental births. A unified framework and world evidence*

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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. Under this behaviour, parents can choose to carry out these pregnancies to term and raise a larger number of children than originally desired, or 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.

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. Under sex-selective abortion, a boy has on average more sisters among her elder siblings. 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 the 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 such 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). We explore the demographic consequences of these gender biased preferences, which 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 in the literature (Arnold, 1985; Basu and de Jong, 2010; Bhalotra and Cochrane, 2010; Jayachandran, 2015). In 2015 for example, among papers mentioning either one of the two terms, only 8% mentioned both, and 87% where exclusively about sex-selective abortion.[2] Today, sex-selective abortion is seen as independent from the stopping rule, and the stopping rule itself is rarely studied anymore.[3]

We claim that these two practices should be analyzed together, as they share fundamental similarities. Think of two families which desire one son and no daughter, the first using the stopping rule and the second, sex-selective abortion. Focusing on pregnancies, their behaviour is identical: they carry on when the foetus is a girl and they stop when the foetus is a boy. Simply, girls are born in one case and aborted in the other. 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 desired gender composition is reached.[4] Under this behaviour, children of the undesired gender 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 not been considered under that light.[6]

[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] We conducted a search on Jstor for the words "stopping rule" alone, "sex-selective abortion" alone, and both combined appear at least once. 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] 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 technical: studying sex-selective abortion together with the stopping rule poses specific challenges, as discussed below.

[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.

[6] See a non technical summary of some of the intuitions of this paper in French in Baland et al. (Forthcoming).

Given their equivalence in terms of pregnancies, studying these two technologies jointly is important because of the policy trade-offs involved. Both 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; Cassan and Van Steenvoort, 2024). They are 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 children (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 abortions are costly for mothers and lead to skewed sex ratios at the society level: too few girls are born as compared to boys (Sen, 1990; Anderson and Ray, 2010; Bhalotra and Cochrane, 2010; Anukriti et al., 2022; 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). In this paper, we highlight the substitutability of these two technologies, as a policy targeting one technology directly affects the prevalence of the other. Thus, a policy which forbids or increases the cost of sex-selective abortion (Nandi and Deolalikar, 2013; Darnovsky, 2009) leads to more instrumental births. Consequently, it is not clear that this particular policy is desirable per se (as discussed in Das Gupta (2019), see also Mohapatra (2013)). By contrast, some countries increase the cost of instrumental births by penalizing large families (e.g. the one child policy in China), inducing parents to turn to sex-selective abortions.

We therefore 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 depending on their relative costs. We derive tests allowing to detect instrumental births and sex-selective abortions and quantify their relative prevalence. These tests can be applied without any further assumption or prior knowledge about gender preferences. In particular, they do not require the use of a natural sex ratio, which fails to provide a reliable benchmark (see Anderson and Ray (2010); Bongaarts and Guilmoto (2015)): the 'natural' sex ratio varies across human groups between 103 and 107 boys per 100 girls (see Appendix H and (Chahnazarian, 1988; Waldron, 1998)) and fluctuates 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 this as a well-defined benchmark (see, for instance, Bruckner et al. (2010) and Catalano and Bruckner (2005)).[7]

[7] 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. 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. The use of the sex ratio as birth to detect sex-selective abortion has also been criticized (Dubuc and Sivia, 2018) for offering a potentially biased view of the *proportion* of parents practicing abortion in the presence of decreasing desired fertility.

Our formalization takes the perspective of the child rather than that of families with completed fertility. Building on Yamaguchi (1989), Arnold et al. (1998) and Ray (1998), we show that, under the stopping rule and a preference for sons, a female foetus is on average followed by more pregnancies than a male foetus (of the same rank), but faces the same history for the preceding pregnancies. In the absence of sex-selective abortion, girls have on average more younger siblings than boys, but the same number and gender distribution of elder siblings. This approach 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 we show, all these are direct consequences of girls having more younger siblings than boys under the stopping rule.

This result also suggests a simple method to identify countries 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. 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 the stopping rule.

Over the recent years, the practice of sex-selective abortion developed rapidly. As reliable information on pregnancies and abortions is typically not available, the literature focuses on the evolution of the sex ratio at birth over time (Guilmoto, 2009; Guilmoto and Duthé, 2013; Bongaarts and Guilmoto, 2015) 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 often exploits the empirical fact that sex-selective abortion tends to be practiced at later birth ranks: it looks at how sex ratios at birth change 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.[8] We formalize this insight by showing that, when instrumental births and sex-selective abortions are not too costly, parents always prefer to postpone sex-selective abortions. They start with instrumental births and switch to sex-selective abortions in later births, when unsatisfied with the gender composition of their first births. This is because the opportunity cost of instrumental births becomes larger in the last births, when the birth of an instrumental girl (boy) prevents the family from reaching its desired number of sons (girls).

Absent sex-selective abortion, the proportion of boys and girls among elder siblings is independent of the

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

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. (Conversely, a boy is more likely to be born if he has many elder sisters.) As a result a difference across gender in the proportion of boys among elder siblings is evidence of sex-selective abortion. This is the basis of our test, and we find that sex-selective abortion is essentially practiced 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. In the process, we estimate 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 are by far more prevalent than sex-selective abortions. In fact, instrumental births are typically two to three times more prevalent than missing births. Studying sex-selective abortion only is studying only the tip of the iceberg of the stopping rule.

The structure of the paper is as follows: we first develop a simple formalization of instrumental births and of sex-selective abortion. We then present our tests to detect the prevalence of either phenomena. Applying these tests, we identify the countries in which the instrumental births or sex-selective abortion prevail, and quantify their relative importance.

2 The demographic consequences of the stopping rule

2.1 The stopping rule and the number of younger siblings

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 are one unit closer to their objective. When a female is "drawn", parents make no progress as the female foetus does not contribute to their desired number of boys. Additional pregnancies (draws) are then required in order to compensate for this failed attempt - no matter whether the foetus is sex-selectively aborted or not. 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 obtain the male foetus that she is not.

More formally, consider first the simple case in 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. The (male to female) sex ratio at any rank in this population is constant and equal to $\frac{p}{1-p}$, and the 'stopping rule' has no effect on the sex ratio in the aggregate (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, mothers in their k^{th} pregnancy have the same number of $k-1$ pregnancies in the past. On average, 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 a male foetus brings parents one unit closer to their desired number of boys. With a female foetus, parents are not closer to their target and need additional pregnancies to compensate. As a result, a female foetus is expected to be followed by more pregnancies than a male foetus.

Let $\bar{N}$, with $\bar{N} > b^*$, represent the maximum number of pregnancies in a family (which implies that 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^*. Under the stopping rule, if $e = b^*$, the last birth is a boy and no more pregnancies occur.). We denote by $E\left(Y_i\left(k,e\right)\right)$ the expected number of pregnancies that follows a foetus of rank k with e older brothers. We have:

Proposition 1: The expected number of future pregnancies is strictly larger for a female than for a male foetus at any rank k, with $k < \bar{N}$:

$$E\left(Y_g\left(k,e\right)\right) > E\left(Y_b\left(k,e\right)\right), \; \forall k < \bar{N}.$$

Moreover,

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

Proof: See Appendix A

In the absence of abortions, the proposition implies that, at a given 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. For a given $\bar{N}$, the difference in the expected number of subsequent pregnancies is monotonically decreasing in the number of desired boys, b^*. Conversely, for a given b^*, this difference is increasing in $\bar{N}$, as does the male to female ratio of the last pregnancy. As stated in the second part of the proposition, when $\bar{N}$ is very large, this 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. If $p = 1/2$, the mother of a female instead of a male foetus is expected to have 2 more pregnancies.[9] These results easily extend to a situation under which parents also desire a given number of daughters $g^* > 0$, as long as $b^*/g^* > p/(1-p)$. Under this condition, girls will always have more younger siblings. [10]

Figure 1 illustrates our 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. (Of course, the divergence in the number of ever born siblings can *only* be driven by the younger siblings.)

2.2 Sex-selective abortion and the composition of elder siblings

To simplify the discussion, suppose that parents want exactly b^* boys and no girls and let us denote the maximum number of alive births by $\bar{N}^*$, with $\bar{N} \geq \bar{N}^* \geq b^*$. The 'natural' probability of having a boy out of each pregnancy is given by p. Each abortion implies a cost $C_{ssa} > 0$ to the parents. Given this cost, 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, an abortion at pregnancy j implies a cost of C_{ssa}. By postponing to the next rank, this cost only occurs with probability $(1-p)$: future abortions are, in expected terms, always less costly than the current one. This also implies that, once a couple decides to practice sex-selective abortion, other abortions are also carried out on all future female foetuses. We therefore have:

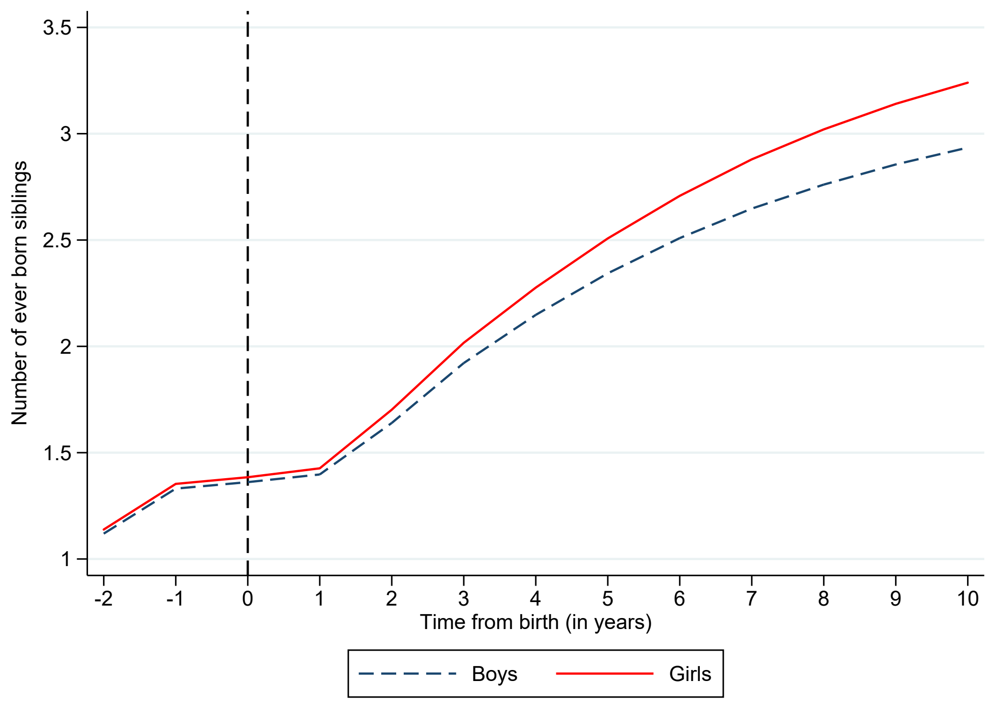
Lemma: Once, for a given pregnancy, sex-selective abortion is chosen, sex-selective abortion is chosen for all future pregnancies.

That sex-selective abortion is applied at later ranks is supported by a large body of evidence (see e.g. Lin et al. (2014)). In families which only had daughters in their previous pregnancies, parents adopt sex-selective abortion starting at rank $\bar{N}^* - b^* + 1$. More generally, for those families that did not yet 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,

[9] 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 make this prediction more precise by showing that these outcomes can only be driven by younger siblings.

[10] Note that similar results can be found using an alternative model, explored in Appendix B, in which parents have lexicographic preferences over the number of children and the number of sons. Under these preferences, a fall in the ideal family size leads to an increase in the difference in younger siblings (see also (Guilmoto, 2009; Jayachandran, 2017)).

Figure 1: 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.

full sex-selection is expected in the last rank, $k = \bar{N}^*$. As a result, at each rank $k \geq \bar{N}^* - b^* + 1$, sex-selective abortion is practiced by those families with not enough sons and too many daughters in the early ranks. This observation implies that the proportion of girls among elder siblings is, on average, larger for a boy of rank $k \geq \bar{N}^* - b^* + 1$ than for a girl of the same rank. In particular, the probability that the sibling of rank $k-1$ is a girl is also larger. We therefore have:

Proposition 2: Under sex-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.

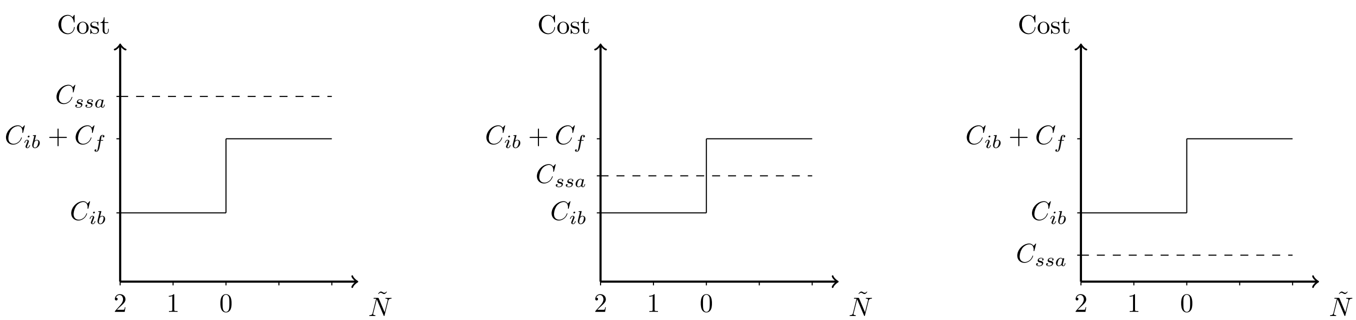
The argument can be generalized to settings in which parents also want a given number of daughters. As a matter of fact, as long as $b^*/g^* < p/(1-p)$, the proportion of boys among elder siblings is larger for a girl than for a boy. That is, the proportion of girls among elder siblings is larger for a boy than for a girl. The proposition simply describes the consequences of biased preferences, regardless of the preferred gender.

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, C_{ssa}, to the cost of an (additional) instrumental child, C_{ib}, which we assume constant. The cost of not reaching their desired gender composition is denoted by C_f, which occurs when the number of births left available is lower than the number of boys or girls that still remain to be born. Comparing these costs, three cases are possible. They are illustrated in Figure 2, where $\tilde{N}$ represents the number of 'feasible draws', that is the number of additional births for which reaching the desired gender composition is still feasible.[11].

If $C_{ssa} > C_{ib} + C_f$ at all ranks, sex-selective abortion is never practiced and, at each rank, part of the births are "instrumental" (Figure 2a). By contrast, when $C_{ssa} < C_{ib}$ at all ranks, parents always resort to sex-selective abortions for each foetus of the undesired gender and no instrumental birth occur (Figure 2c). More interesting is the case illustrated in Figure 2b in which the cost of an abortion lies in-between, $C_{ib} + C_f > C_{ssa} > C_{ib}$. 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, i.e., when $\tilde{N} = 0$.

Figure 2: 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

The possibility of sex-selective abortions does not therefore imply the disappearance of instrumental births. In the case illustrated in Figure 2b, 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 families which desire two boys and one girl, with $p = 1/2$ and $\bar{N} = 5$. Among all possible

[11]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.

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 always 'instrumental' since she was not desired per se, but is born as the 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 $1 - p$.[12] In other words, $1 - p$ girls should have been born but have been replaced by a boy and are therefore 'missing'. Among these five births, we have two 'instrumental' and $1 - p$ 'missing' girls. (In Appendix C we generalize this insight in a simple framework, showing that the quantitative prevalence of instrumental births largely dominates that of sex-selective abortions.)

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 children. 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 the sum of these two measures is exactly equal to the share of instrumental births that would have occurred in the absence of abortion.[13] This is because our measure of missing children does not (and cannot) measure the actual number of abortions but the number of foetuses that have been replaced by a child of the desired gender. Absent abortion, these foetuses would be born and counted as instrumental births. This property strikingly illustrates this idea that instrumental births and sex-selective abortion are the two complementary expressions of the stopping rule.

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.

[12] 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 already larger than 0.98.

[13] 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.

3 Prevalence of the stopping rule across countries

3.1 Data

In our empirical analysis, we use the Demographic and Health Survey (DHS) of all countries and all years prior to 2022. This represents 82 countries, 2,995,509 mothers and 10,361,884 births.[14] 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. For the detection of instrumental births (Section 3.2.1) we use the full sample, as this technology is always available. For the detection of sex-selective abortion (Section 3.2.2) and for the estimation of the prevalence of the stopping rule (Section 3.4), 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.[15]

3.2 Detecting the stopping rule

3.2.1 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 the stopping rule. To test the presence of instrumental births, we simply compare the difference in the number of younger siblings between 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.

To illustrate our approach, we run, by age and by rank, the following estimations for India, known for its biased prefererence, and Bolivia, which we presume to be gender neutral:

$$\text{younger siblings}_{it} = \sum_{t=0}^{T} (\alpha_t * \text{age}_{it} + \beta_t * \text{female}_i * \text{age}_{it}) + \epsilon_{it} \tag{1}$$

$$\text{younger siblings}_{ik} = \sum_{k=1}^{K} (\alpha_k * \text{rank}_{ik} + \beta_k * \text{female}_i * \text{rank}_{ik}) + \epsilon_{ik} \tag{2}$$

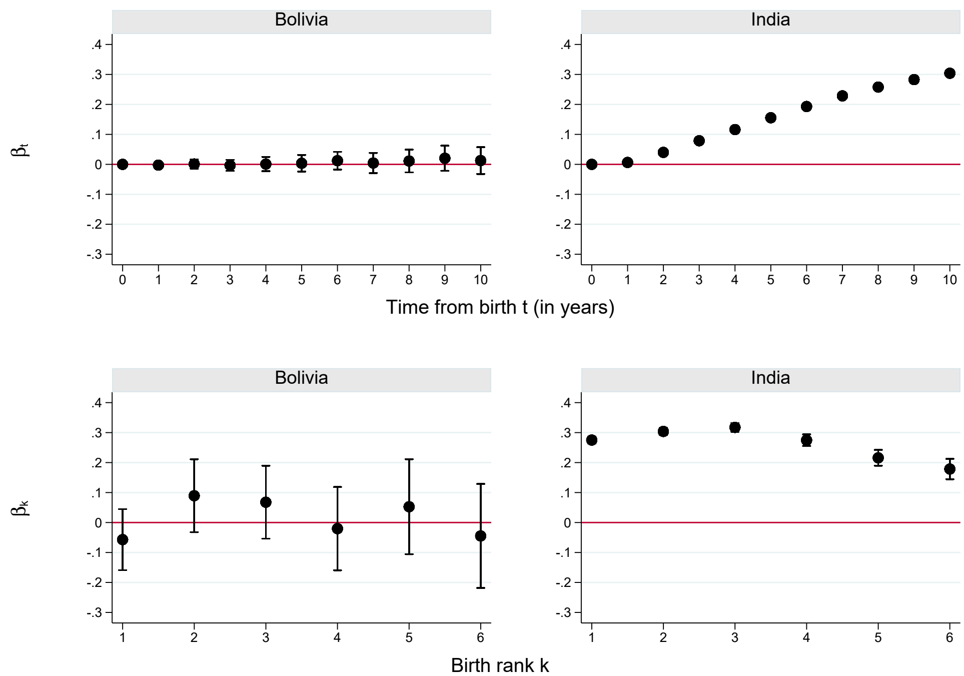
where $\textit{younger siblings}_{ij}$ is the number of ever born younger siblings of child i at age $j = t$ or at rank $j = k$. For each child aged between zero and ten (indicated by a set of dummies age_{it}) or between ranks 1 to 6 (dummies $rank_{ik}$), we record all her younger siblings at each age, with an age or rank-varying number of younger siblings. $female_i$ indicates if the child is a female. (We also cluster standard errors at the primary sampling unit and

[14] See https://dhsprogram.com/data/available-datasets.cfm for the list and descriptions of surveyed countries.

[15] 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.

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 3 below reports our estimates.

Figure 3: 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 3 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 1 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.

Turning to all the countries surveyed, we estimate for each country the following equation, which replicates equations 1 and 2 averaged across ages and ranks:[16]

[16]We make use here of the fact that the difference in the number of younger siblings prevails at all ranks and ages. Note that, under instrumental births, the average birth order of girls is lower than that of boys (Basu and de Jong, 2010). When aggregating over all ranks, our measure is therefore, in absolute value, biased upwards. Since this is a direct consequence of instrumental births, this is of no consequence as a test of 'detection' of instrumental births.

$$\text{younger siblings}_i = \beta * \text{female}_i + \epsilon_i \quad (3)$$

The coefficient β corresponds to the difference in the average number of younger siblings a girl faces compared to a boy. The estimated coefficients for each country are presented in Appendix D. We find a substantial cluster of countries with a very high difference in the number of younger siblings. 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. These countries are not often associated with the practice of instrumental births (Ebenstein (2014) is a notable exception).

Second, a few countries (Cambodia, Cameroon, Colombia, DR Congo, Haiti, Indonesia, Mali, Niger, Nigeria and Trinidad), display a small but negative coefficient, suggesting the presence of a stopping rule favoring girls and not boys.[17] This possibility is hardly mentioned in the 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 below.)

We could equally well perform these detection tests on particular subsamples, by taking children of a particular age or of a particular rank as in the India-Bolivia comparison. When focussing on children of a particular age, the measure at young ages is influenced by birth spacing, which may vary across gender (see in particular Jayachandran (2015)). This in itself is not an 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, focusing on older children applies 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 results are robust to the choice of a specific age group. 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 instrumental births. A test on the eldest child uses enough information for the test to be valid and requires only to know the gender of the eldest child and the number of his younger siblings. In doing so however, we neglect useful information related to the consequences of the gender of a child of lower rank. In a 'small' sample, focusing on a particular rank therefore provides a sufficient but not a necessary test of the instrumental births.

[17] 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)

3.2.2 Sex-selective Abortion

Our test of sex-selective abortion compares at the child level the gender composition of his or her elder siblings.[18] 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. When sex-selective abortion applies, boys of a given rank tend to have more sisters (and girls more brothers) among their elder siblings.[19] Our first test relies on the following estimation:

$$\text{share girls elders}_{it} = \sum_t (\gamma_t * \text{year}_{it} + \delta_t * \text{male}_i * \text{year}_{it}) + \epsilon_{it} \tag{4}$$

where *share girls elders*$_{it}$ is the share of sisters among alive elder siblings of a child i born in year t.[20] Note that, unlike our detection test for instrumental births, the coefficient of interest does not vary with age, since the composition of elder siblings is given at birth. We carry out our estimations for different cohorts (birth years t) so as to compare the current situation to that prevailing before the spread of ultra-sound technologies. Alternatively, we can also test the prevalence of sex-selective abortion by focusing on children of specific ranks k over a given period:

$$\text{share girls elders}_{ik} = \sum_k (\gamma_k * \text{rank}_{ik} + \delta_k * \text{male}_i * \text{rank}_{ik}) + \epsilon_{ik} \tag{5}$$

Focusing again on India and Bolivia, the top panel of Figure 4 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. 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. Our measure finely detects the rise of sex-selective abortion in India. Since sex-selective abortion technology became widespread only in the late 1990s worlwide, we now apply our test only on post-2000 births.

We again carried out our tests across all countries which, for the sake of presentation, is based on a simplified version of equation 5, averaging over all ranks:

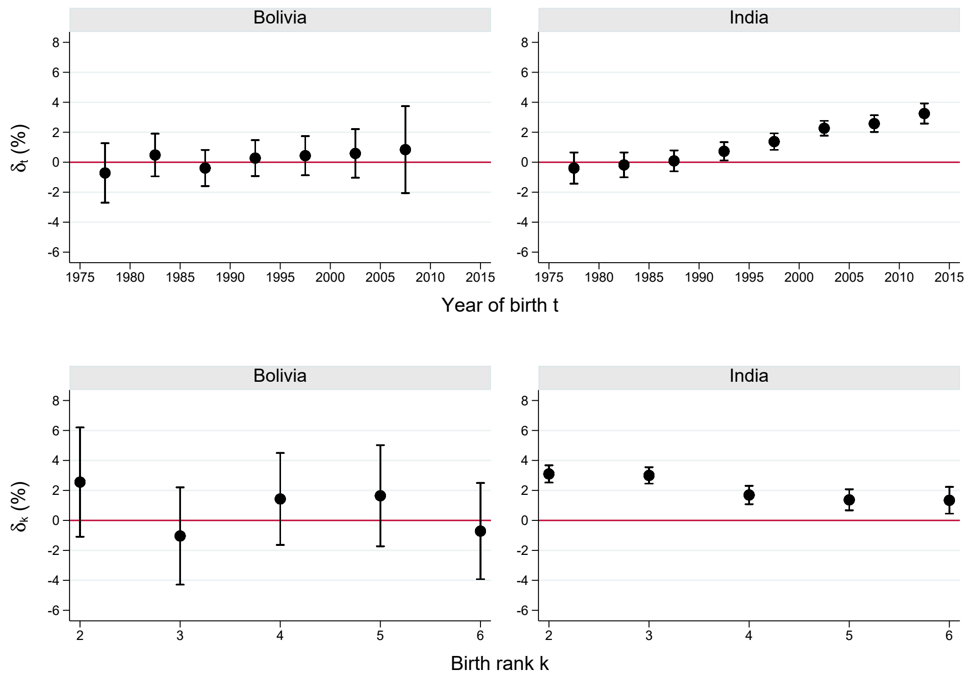
$$\text{share girls elders}_i = \delta * \text{male}_i + \epsilon_i \tag{6}$$

[18] An alternative test could simply focus on the gender of the preceding child. While less efficient, it also provides a sufficient condition for detecting sex-selective abortion.

[19] Note that it is also the case that boys have more sisters among their *younger* siblings compared to girls. Nevertheless, even in the absence of sex-selective abortion, the gender distribution among younger siblings is not the same for boys and girls, as girls have more younger siblings under the stopping rule.

[20] 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 4: 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.

The δ coefficient, estimated separately for each country, in the average proportion of girls among elder siblings of girls as compared to boys. The estimated coefficients are given in Appendix D. Owing to the limited availability of the ultra-sound technology, fewer countries are identified as practicing sex-selective abortion than practicing instrumental births, among which finds India, Albania, Armenia, Azerbaidjan and Tajikistan (which also practice instrumental births), but also Ukraine. At much lower levels of significance, one also finds Cote d'Ivoire, Ethiopia, Namibia and Zimbabwe.

3.3 Limits of our approach

The measures we propose are by themselves meaningful. Thus, our test of instrumental births (equation 3) directly provides a measure of the sibling competition a girl is exposed to compared to a boy. Our test of sex-selective abortion (equation 6) is a direct measure of gender diversity within families. However, the estimated coefficients do not provide a measure of the intensity of biased gender preferences, as the latter depend on the desired number of boys and girls as well as the maximal family size, which vary across time and space.[21] The next section provides an attempt at estimating those biases, at the expense of additional assumptions.

Also, our tests only capture biases in fertility preferences. Thus, if $\frac{b^*}{g^*} = \frac{p}{1-p}$, 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 groups that have no preference regarding the gender of their children and groups that apply the stopping rule to achieve an equal number of boys and girls, or groups in which 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, and we discuss in Appendix E their relative performance. 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. In particular, since sex-selective 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.

Finally, our 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.[22] The sex ratio at birth, with all its shortcomings, turns out to be the only measure available. Second, our test for instrumental births applies to monogamous societies. In 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.) We discuss in Appendix F the performance of our test when data on fertility history is not available (in particular, when only household rosters are available).

3.4 Measuring the prevalence of the stopping rule

We now quantify the prevalence of the stopping rule, and in particular the shares of missing and instrumental children by gender. To measure sex-selective abortions, we simply compare a natural sex ratio to the observed sex ratio, along the spirit of the methodology proposed by Anderson and Ray (2010). For the sake of presentation,

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

[22] 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).

we assume abortion rates to be 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, $N_g^P = (1-p)(N_b + N_g)$. Using this expression, the share of missing girls at birth among all children, m_g is given by:

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

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%.[23]

Measuring the share of instrumental children is a bit more cumbersome, as we need to calibrate a model that structures parental preferences, which we describe in Appendix G. This calibration exercise relies on the assumption that all parents share similar preferences towards children, so that from the observed average fertility behaviour observed in the population, we infer their desired family size and their desired number of girls and boys. Using only the births occurring after 2000, our tests identify 21 countries that apply the stopping rule.[24] We report in Table 1 the following indicators for each of these countries: the desired family size, the desired sex ratio, the actual sex ratio, the share of instrumental boys (girls) among alive boys (girls), the share of instrumental children and the share of missing girls. To compute the share of missing girls at birth, we rely on each country's pre-1980 sex ratio as estimated in Chao et al. (2019) as the natural sex ratio at birth.[25] Note that by construction, the share of missing girls at birth is the net difference between the share of missing girls and the share of missing boys: it computes the missing girls in excess of missing boys, rather than the total share of missing girls. Therefore, it can not be directly compared to the share of instrumental girls. To allow comparison, we compute the share of excess instrumental girls as the difference between the number of instrumental girls and the number of instrumental boys divided by the total number of children. Finally, the last column computes the share of children affected by a gender biased stopping rule as the sum of the share of missing girls and excess instrumental girls.

Among the countries that display a preference for boys, the desired sex ratio varies between 105 (for Namibia)

[23]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, presented below, requires us to focus on children that are actually born.

[24]That is, these 21 countries are detected as using either instrumental births or sex-selective abortions or both by our tests.

[25]See Appendix H for a list of the ratio used.

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. Given this bias, girls are systematically more likely to be instrumental than boys. In Armenia, for instance, 64.4% of girls can be considered as instrumental, against 25.3% of boys. In India, the corresponding figures are 49.6% and 22.7%. Overall, the share of instrumental children hovers around 30%, with a share of instrumental girls almost twice as large as that of boys. On the other hand, 3 countries, Cameroon, Comoros, and Niger display a bias in preferences towards girls.

The share 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 3.8% in India. While by any means large, these figures remain much below those observed for excess instrumental girls. Excess instrumental girls represent 17.4% of all children in Armenia, 4 times more than the share of missing girls, or 10.3% in India, more that double the share of missing girls. In almost all countries, the share of excess instrumental girls is several orders of magnitude larger than that of missing girls. Overall, instrumental births predominate under the stopping rule. Focussing on sex-selective abortion only grossly underestimates the prevalence of the stopping rule.

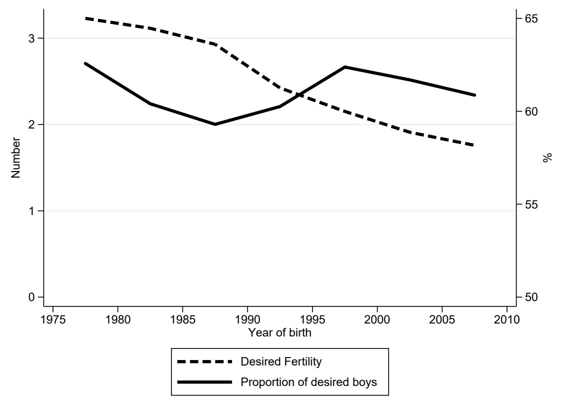
Table 1: Preferences & Fertility

	Desired family size	Desired sex ratio	Actual sex ratio	Proportion of instrumental boys (%)	Proportion of instrumental girls (%)	prop_instru	Missing girls (actual population) (%)	Girls-boy difference in proportion of instrumental (%)	Stopping Rule (%)
Armenia	1.26	232	112	25.26	64.44	43.9	4.35	17.42	21.77
Albania	1.38	207	101	25.95	59.95	42	1.73	14.61	16.34
India	1.84	183	110	22.7	49.61	34.97	3.75	10.26	14.01
Tajikistan	2.54	173	106	16.46	37.13	25.44	2.98	6.81	9.79
Jordan	2.74	169	102	21.98	44.48	32.21	0	8.23	8.23
Nepal	1.81	166	107	27.42	51.06	38.57	0	9.59	9.59
Rwanda	3.06	155	106	14.06	28.22	20.23	0	4.36	4.36
Egypt	2.2	153	105	23.85	42.27	32.38	0	6.77	6.77
Yemen	3.37	146	110	17.45	31.06	23.58	0	4.41	4.41
Afghanistan	3.98	134	109	18.97	29.63	23.9	3.36	3.48	6.84
Bangladesh	1.76	123	107	28.47	37.51	32.83	0	3.36	3.36
Turkey	1.62	122	109	35.69	45.2	40.35	0	3.99	3.99
Ethiopia	3.13	119	108	24.48	31.42	27.82	3.22	2.4	5.62
Pakistan	3.1	117	105	26.83	33.34	29.98	0	2.32	2.32
Cote d Ivoire	2.63	110	109	25.37	29.29	27.29	.	1.35	.
Kenya	2.11	105	101	50.1	52.47	51.29	0	1.22	1.22
Namibia	1.72	105	101	39.6	41.85	40.72	.65	.95	1.6
Colombia	1	100	104	57.62	57.62	57.62	0	0	0
Cameroon	2.76	83	109	27.61	20.72	24	0	-2.26	2.26
Comoros	2.99	82	100	32.81	24.86	28.67	0	-2.78	2.78
Niger	3.87	80	103	19.57	13.47	16.29	0	-1.81	1.81

We finally turn to 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). Panel (a) of Figure 5 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).

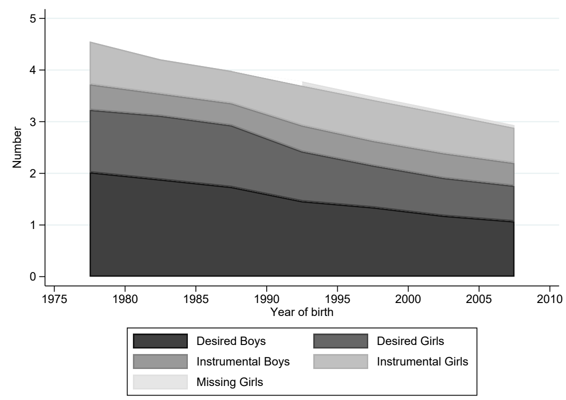
Over the whole period, desired fertility decreased in India from 3.3 in 1980 to 1.75 in the recent years. The proportion of desired boys in total desired fertility is relatively stable at around 60%, which corresponds to a 'desired' sex ratio of 150 boys for 100 girls. Panel (b) of Figure 5 reports for 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 more or less constant with a small decline in the end of the 1980s, which implies that the share of instrumental boys and girls increased throughout. As expected, girls are also more likely to be instrumental.

Figure 5: Evolution of the stopping rule in India



(a) Desired fertility & Proportion of desired boys.

Reading: Over the period 1995-2000, the total desired fertility is 2. The desired proportion of boys is 62%



(b) Desired fertility, proportion of instrumental children and missing girls at birth
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.

Data Source: DHS India 1993, 1999, 2006 and 2015.

Starting after 1990, the number of missing girls at birth is by contrast very modest and stable.

Our methodology can be applied to any sub-population, such as states or castes. In the top panel of Table 2, we replicate our approach over the 17 largest states of India, for all births occuring after 2000. As widely documented in the literature (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.) We do not detect any bias in Kerala. 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.

We do not detect the use of sex-selective abortions in Kerala, Karnataka, West Bengal, Goa and Odisha. By contrast, sex-selective abortion is widely practiced in Haryana and Punjab, where the shares of missing girls are as high as 6.9% and 5.7%. The share of missing girls in states practicing sex-selective abortions fluctuates around 4%. However, the share of instrumental girls remains largely above those figures, indicating again that, in the implementation of the stopping rule, the practice of instrumental births remains preponderant. For instance, the share of excess instrumental girls represents 15.2% of children in Haryana while the share of missing girls is much smaller, at 6.9%. Instrumental births are more than twice as prevalent than missing births in Haryana, the Indian state with the highest share of missing girls.

Table 2: Preferences & Fertility across Indian States and Castes

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

We report in the lower panel of the Table our calibration across castes, distinguishing between the High Castes[26], the Other Backward Castes, the Scheduled Castes, the Scheduled Tribes and the Muslims.[27] 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). The desired sex ratio is on average equal to 246% among high castes but falls to 140% among Muslims. The estimated share of missing girls ranges from 4.7% among High Castes to 0% among Muslims, largely below the share of excess instrumental births.

4 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, or 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.

[26]Defined here as all individuals not belonging to the other categories.

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

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. We show in particular that, in countries in which stopping rule is being practiced, instrumental births remain by far the dominant practice under the stopping rule. Narrowly focussing on sex-selective abortions therefore leads to a large underestimation of the prevalence of the stopping rule.

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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 $E(Y_b(k+1,e) \mid g_k)$ (to indicate that her sibling of rank k is a girl, g), is given by:

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

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

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:

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

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

$$E(Y_g(k,e)) = 1 + pE(Y_b(k+1,e) \mid g_k) + (1-p)E(Y_g(k+1,e) \mid g_k)$$

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

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

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

□

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.

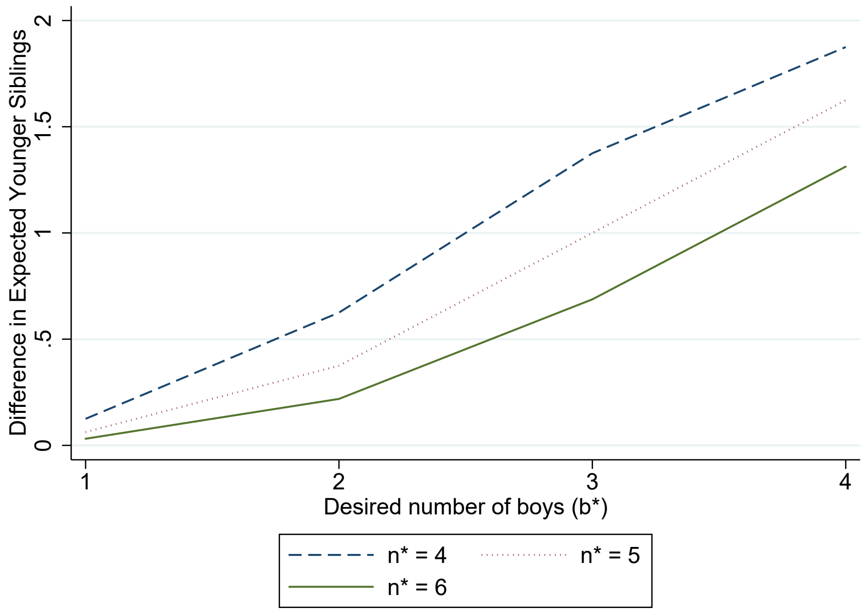
Consider first a family that succeeds in having at least b^* boys with n^*children. In such families, at any rank k, girls and boys have exactly the same number of younger siblings, which is equal to $(n^* - k)$. The proportion of such families in a large population is equal to the probability of having at least b^* 'successes' (boys) in n^* trials (children), which we denote as above $\sum_{j=b^*}^{n^*} B(j, n^*)$. 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 $\sum_{j=0}^{b^*-1} B(j, n^*)$. We therefore have:

Proposition 3: In families with lexicographic preferences over (b^*, n^*), at any rank, girls have in expected terms $\left(\frac{1}{p}\sum_{j=0}^{b^*-1} B(j, n^*)\right)$ 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 $\left(\frac{1}{p}\sum_{j=0}^{b^*-1} B(j, n^*)\right)$ more younger siblings than a boy. A closer examination of this expression is illustrated in Figure 6: 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 6: 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 Decomposing the stopping rule between instrumental births and missing births

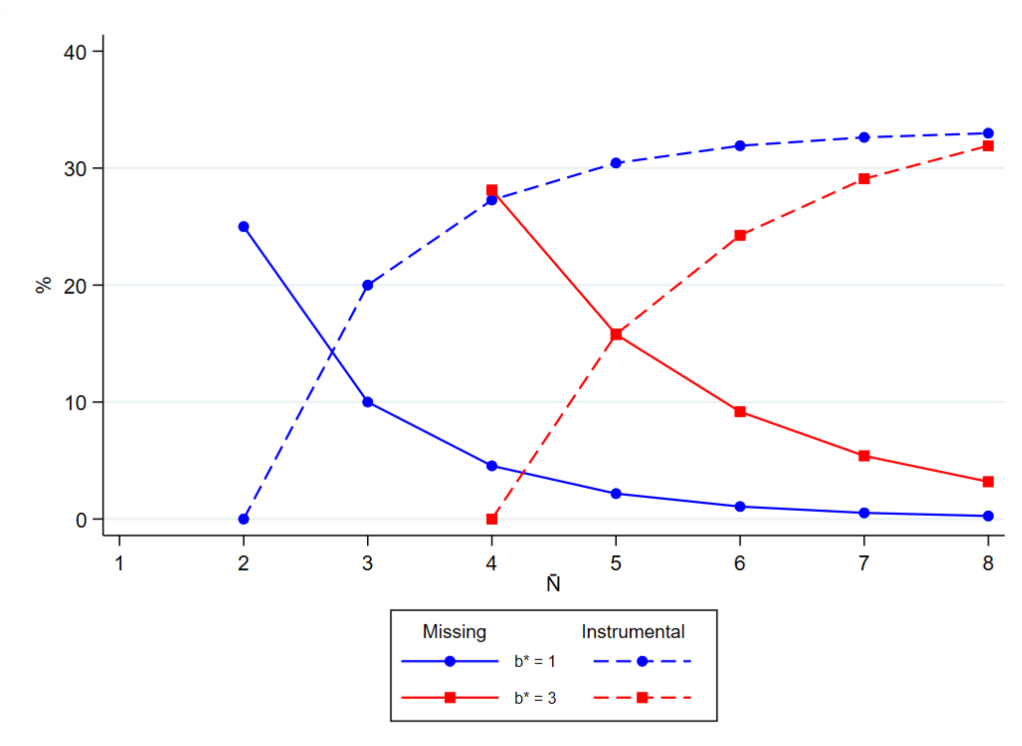
We analyze here the relative importance of instrumental births and missing births as a function of both the desired number of boys (b^*) and the maximum number of children ($\bar{N}$). We show that even when sex-selective abortions substitute for instrumental births, the latter remain quantitatively significant for various values of b^* and $\bar{N}$. In Figure 7 we compute the share of instrumental births and missing children observed in families that desire 1 girl and either 1 or 3 boys[28], 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 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

[28] With a probability $p = 0.5$ to have a son.

’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%.[29]

Figure 7: 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 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.

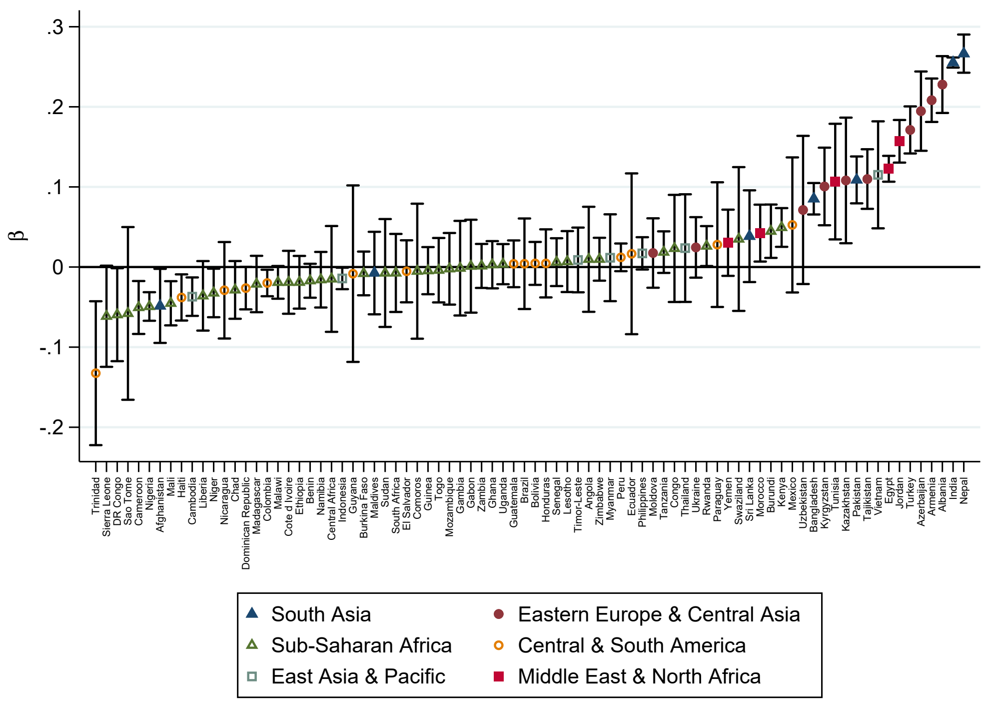
[29] This is in line with (Jayachandran, 2017) who highlights the increased occurrence of abortions under declining fertility. In the context of our model, we indeed observe an increase in the share of missing children, and therefore in the occurrence of abortion, as the maximum family size decreases.

D The detection of instrumental births and sex-selective abortion: country level results

D.1 Instrumental births

We show here the results of our test of detection of instrumental births described in Section 3.2.1. Figure 8 presents 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.

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

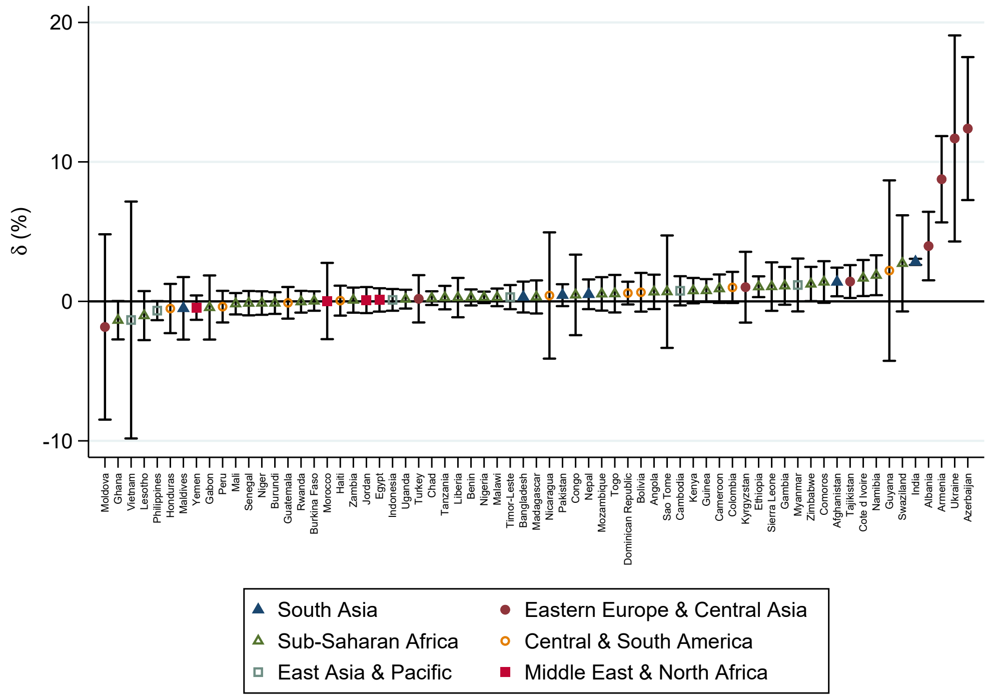


Data Source: All DHS.
Reading: In Nepal, girls have on average 0.27 more younger siblings than boys.

D.2 Sex-selective abortions

We show here the results of our test of detection of sex-selective abortions described in Section 3.2.2. Figure 9 presents the δ coefficients by increasing order of magnitude.

Figure 9: 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.

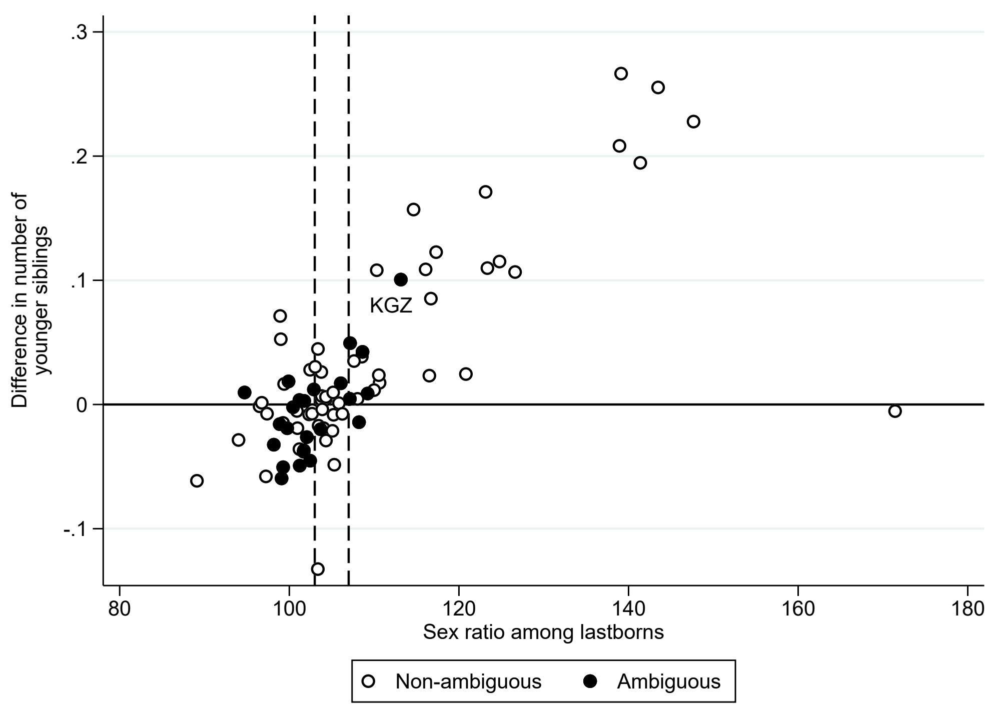
E Comparison with other approaches

E.1 The stopping rule and 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 to a counterfactual sex ratio, typically the "natural" sex ratio. While intuitive, this approach suffers from some important shortcomings. First, as discussed in the introduction, there is no universal natural sex ratio at birth. Second, by focusing on the gender of the last born, this approach requires families with completed fertility and thereby 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 the 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 of reference. Given the uncertainty surrounding its precise value, we run the test for two plausible values of this ratio, 103 and 107.[30] In Figure 10 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.

Figure 10: 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.

The Figure also illustrates the poor performance of methods based on the sex ratio of the last born. For 71% of countries (the white dots), 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).[31] By contrast, for the other countries (the black

[30] Clearly, the comparison is even less favourable to the sex ratio of the last born for more extreme, but plausible, values of the benchmark.
[31] Our test agrees with 84% of them.

dots), the conclusion is ambiguous. According to our test, the stopping rule prevails in half of these cases.[32] Thus, Kyrgyzstan, Morocco and Kenya, for instance, apply the stopping rule against girls according to our test, but fail to be detected by the sex ratio of the last born when a cut-off ratio of 107 is used.

E.2 Other popular measures

Another method used in demography to detect the stopping rule 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.[33] 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 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, even if differential the reduction of birth spacing could be considered sufficient, it is not a necessary

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

[33] 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.

step to do so. Therefore, while the detection of a gender difference in birth spacing may imply 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; Pörtner, 2022).

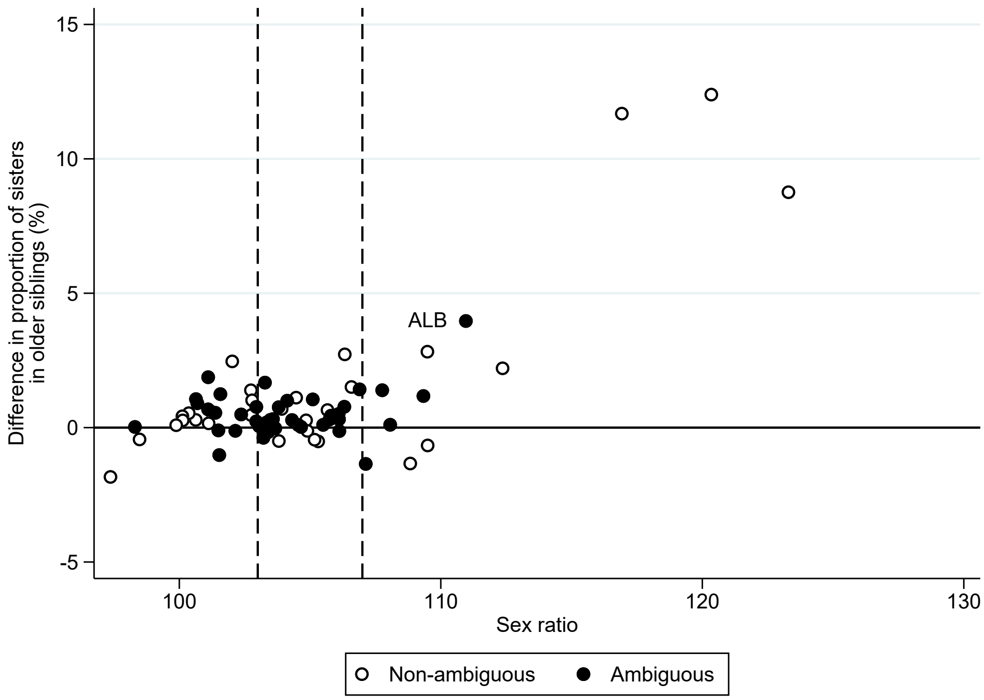
A last set of measures proposed in the literature is based on the consequences of the stopping rule. According to Basu and de Jong (2010), girls tend to be born in larger families and to have, within families, earlier ranks than boys (see also Yamaguchi (1989)). However, as shown in Section 2, girls 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.

E.3 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 11 reports the value obtained under our measure (on the vertical axis) and the corresponding value of the observed sex ratio (on the horizontal axis).

Figure 11: 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.

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 ambiguous cases represent the remaining 57% of our sample. Among these, 18 % (7 countries) are identified by our test as practicing sex-selective abortion. This is the case, for instance, of Albania or Afghanistan for which the traditional approach remains inconclusive with a benchmark of 107.

F 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.[34] 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. (The discussion below also applies to the case of selective recall biases, whereby, compared to elder boys, elder girls who died in early age are more frequently under-reported.)

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.

Under 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

[34] 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.

this underestimation is symmetric across gender which 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 this 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, the use of household roster surveys leads our tests to overestimate the presence of sex-selective abortion.

Our tests rely on fertiliy history. This information may not be systematically available. 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.

G The calibration of the preferred gender composition

To estimate the desired number of boys and girls, we use a 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[35]:

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

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

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

[35]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.

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 $f_{X_g}(x; b^*, g^* - 1, p)$.[36] 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 family size and composition (given the distribution above). This property is directly related to our previous observation according to which focusing 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^*.[37] 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.[38]

H "Natural" sex ratios

Table 3 presents the average sex ratios estimated between 1950 and 1980 by Chao et al. (2019) that we use as the "natural" sex ratio of reference in our estimation of missing girls at birth.

[36] 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^*.

[37] 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.

[38] 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.

Table 3: "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