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SEX SELECTION AND THE INDIAN MARRIAGE MARKET

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Abstract

I consider the widespread phenomenon of sex ratios skewed by parental preference. Edlund (1999) proposes that if parents prefer sons and permit only women to marry up in social class, sexes will segregate by wealth in equilibrium. Using data on 30,000 Indian children, I show that parents indeed consider the marital prospects of their children when sex selecting. This leads to the average marriageable woman being poorer than her male counterpart, a compositional shift which generates asymmetry in marriage matches and bargaining power. The results underscore the importance of incorporating compositional shifts into standard models of scarcity in marriage markets.

Keywords: Sex Selection, Marriage Market, Bargaining Power
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1 Introduction

Consider a poor woman in search of a husband in the north Indian state of Haryana. She may entertain many suitors: the parents in her and neighboring villages preferred sons to daughters, so they used sex selection technology on occasion to abort their female fetuses. She may also find that many of her suitors are wealthier than she: compared to the poor, the wealthy families in her neighborhood bore relatively more sons than daughters, now leaving a glut of rich single men. Both of these channels - scarcity of competitors and availability of higher status partners - may improve the lot of this young woman. But where are her wealthier female counterparts? And what is her bargaining power in a match such as this?

This study builds off of a literature that documents the rise in child sex ratios, or the fraction of boys to girls, across India in parallel with the expansion of ultrasound technology (Chen, Li, and Meng, 2013; Bhalotra and Cochrane, 2010) , as well as evidence that such sex ratios are differentially more skewed towards males among the wealthy than the poor (Sen, 1985; Murthi, Guio, and Drèze, 1995; Gupta, 1987; Bhalotra and Cochrane, 2010; Akbulut-Yuksel and Rosenblum, 2012; Anukriti, Bhalotra, and Tam, 2018; Borker et al., 2018).[1] I ask two questions. First, why are sex ratios stratified by wealth? If stratification is due to the price of sex selection technology, then it should disappear as the technology becomes increasingly affordable. However, if stratification is the result of deeper cultural norms and parental preferences, the implications of easier access to sex selection technology may be more dismal.[2] In particular, Edlund (1999) proposes that, if parents place value on their children marrying (for example as a means of passing on wealth or genes through grandchildren), if they hold a preference for sons over daughters, and if marital matches occur in a context of female hypergamy[3], sex ratios will be stratified by wealth in equilibrium. Wealthy parents

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[1] The theory that sex ratios are more likely to be skewed towards males among high-status populations than low-status populations was first proposed by Trivers and Willard (1973) in their seminal paper on parental ability to affect their offsprings' sex, and has been found to hold true across a wide variety of animal species including humans. The mechanism behind this pattern, however, varies widely from prenatal biological changes to active postnatal decisions. This paper focuses on the latter. See Edlund (1999) for a deeper exploration of the empirical tests of the Trivers and Willard (1973) hypothesis.

[2] Beyond the seminal work of Edlund (1999) and variations in theoretical framing by Bhaskar (2011) and Borker et al. (2018), most related literature presents a long run optimistic view of the expansion of ultrasound technology: skewed sex ratios will eventually self-correct given supply and demand (Park and Cho, 1995), and surviving daughters will be treated better since ultrasound may be a substitute for postnatal discrimination (Goodkind, 1996; Hu and Schlosser, 2015).

[3] Hypergamy is the socially more accepted form of mixed-class unions, in which poor women may marry wealthier men, but wealthy women cannot marry poorer men (Edlund, 1999); though prevalent across cultures (Zentner and Mitura, 2012), some argue that the strict caste system in Hindu societies reinforced the need for female hypergamy, as most caste identities are patrilineal (Blunt, 1931; Davis, 1941; Bidner and Eswaran, 2015). In other words, a man may marry outside his caste to one below because his wife and children will assume his higher caste; a woman who marries outside her caste to one below will assume the lower caste of her husband, jeopardizing the purity of the higher caste.

will sex select actively for sons, while poor families, aware that the sons they bear will not be competitive against wealthier men in their future marriage market, will refrain from sex selection or select for daughters. In such an environment, wealth stratification will remain, or even be exacerbated, by easier access to ultrasound, manifesting in a permanent female underclass.[4]

Second, what are the implications of wealth-stratified sex ratios on the matches formed in the marriage market and subsequent bargaining power of the average married woman? I extend Edlund's theory to argue that if sex ratios are skewed disproportionately amongst the rich, then the average match in the marriage market will occur between a poorer woman and a wealthier man. This match may place the average female in a weaker bargaining position within the marriage. This result is in stark contrast to standard economic models of the marriage market, which predict that scarcity of females should raise a woman's bargaining power. Standard theory ignores the compositional effect inherent in the source of skewed ratios: the average woman in a market where she is scarce due to endogenous sex selection is also a *poorer* woman. This paper explores the distribution of bargaining power in such a match, relative to that of her less scarce, but wealthier, counterfactual in a world without such sex selection.

To tackle the first question, I document a series of patterns consistent with Edlund's theory using a nationally representative dataset of 30,000 children in India: parents select the sex of their [unborn] child, not only according to their preference for sons, but also according to the state of the child's anticipated marriage market. A back-of-the-envelope calculation suggests that at least 60% of the prevailing sex ratio gap by wealth can be explained by poor parents who actively *refrain* from selecting for sons due to their child's future marital prospects, rather than merely an inability to afford ultrasound technology.

These wealth-stratified sex ratios have important implications for the quality of matches in the marriage market of affected children. To answer the second question, I exploit temporal and geographic variation in access to sex-selection technology and present evidence that

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[4] An elegant paper by Borker et al. (2018) proposes a model that endogenizes son preference and hypergamy using two inefficiences in the Indian marriage market: leakage in a daughter's bequest, or dowry, due to patrilocal customs, and leakage of a son's bequest due to consumption by the wife. Using data on dowry payments in South India, the authors document within-caste stratification of sex ratios by wealth, with a wealth gap in marriage that is decreasing with parental wealth and a positive bride price at every level of wealth. The first two results are consistent with the predictions of Edlund (1999); the latter is not: Edlund's exogenous son preference predicts a negative bride price (as parents of sons in high sex ratio regimes will wish to subsidize the production of daughters by other families). However, for the objectives of this paper, the direction of the bride price is not relevant: the underlying assumption in both models is that parents internalize the marital prospects of their children when determining the sex composition of their family, and in hypergamic settings, this yields segregation of the sexes by wealth. This is the assumption I test. For consistency with Borker et al. (2018), I present results on stratification of sex ratios with and without caste fixed effects.

females married to men who were born into high sex-selection regimes have lower education and poorer health (consistent with sex ratios disproportionately male-skewed amongst the wealthy at birth), greater marriage age and education gaps (consistent with poorer matching at marriage), and lower domestic safety and power in fertility decisions (consistent with lower bargaining power in marriage) than their unexposed counterparts. These effects cannot be explained by differential treatment at birth, village preference for males, or demand for the sex selection technology alone.

The contributions of this work are twofold. First, the study complicates the standard economic model of marital matching in environments with skewed sex ratios. Existing work exploit unique historical events (migration flows of primarily men; post-war environments with a dearth of men) which serve as effective illustrations of the market mechanism of scarcity. However, none consider the more ubiquitous cause of skewed sex ratios: parental choice and sex selection technology. Sex imbalance of this sort faces an endogeneity challenge: parental choice informs not only the balance of men to women in society, but also how each is treated and what wealth strata each belongs to, both of which in turn affect bargaining power in a marriage match. This is an essential complication to consider, as sex ratios skewed by parental choice are a feature of much of India, China, and the Caucases, affecting approximately 40% of the global population and resulting in an estimated 45 million missing female births (Chao et al., 2019)

Second, while previous studies have established that the wealthy sex select more than the poor, this is the first empirical investigation to probe the underlying mechanism of parental internalization of marital prospects first proposed by Edlund (1999).Wealth stratification in sex ratios necessarily implies that the average female in a society is poorer than the average male. Efforts to improve the status and treatment of women will be undermined by this compositional feature of Indian society, and understanding the source of this stratification is essential to designing effective policy. If stratification of sex ratios by wealth is due to lack of affordability of ultrasound, innovations in the technology will reduce the imbalance across wealth (while inevitably exacerbating the total skewness of the population).[5] If it is due to a higher social cost of bearing a female among the wealthy, campaigns aimed at raising the social value of a daughter may reduce both stratification and average skew.[6] However, if it

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[5] Yet the solution is not as easy as banning ultrasound technology, whose intended purpose is detection of fetal abnormalities, not sex selection. Numerous state and federal laws in India have instead sought to ban the use of ultrasound technology for the purpose of sex selection (ex. Pre-conception Pre-Natal Diagnostic Techniquest Act (PCPNDT Act) of 1996 and 2003), but these have proven ineffective, as doctors may easily convey the sex of the child using means other than writing.

[6] The recent #SelfiewithDaughter campaign in India may be one example of a modest effort directed towards the more affluent Indian population. These are rare, as most female empowerment campaigns are ironically aimed at the urban and rural poor (see literature on India's *Beti Bachao, Beti Padhao* (Save

is due to parental expectations of their child's marriage prospects, even a small preference for sons over daughters may yield large imbalances across wealth strata, as poor parents must *respond* to wealthy parents' preferences when determining the sex composition of their own children. In such a setting, a deeper shift in norms may be required: a reduction in son preference paired with an easing in cultural practices of hypergamy. Given the close links between hypergamy and the rigid patrilineal caste structures present in much of Indian society, this is an especially tall order (Blunt, 1931; Davis, 1941; Bidner and Eswaran, 2015).[7] [8]

My analysis addresses the two main questions through a series of five steps. First, I present evidence that parents, when determining the sex composition of their own family, take into consideration the anticipated sex composition of their (unborn) child's marriage market. In regions where the marriage market is especially skewed towards males, new parents are significantly less likely to sex select for a son. As predicted by the theory, the magnitude and direction of the response is dependent upon the wealth of the family: in such male-skewed marriage markets, poor parents, using the present marriage market as a proxy for their child's future prospects, respond differentially more than wealthy parents by reducing their degree of sex selection. The result is robust to controlling for the region's intrinsic son preference (as proxied for using the number of adolescent boys in the village - those who are neither part of the marriage market nor being conceived by new parents). Neither can such patterns be explained through a story of credit constraints where the poor simply cannot afford to sex select while the rich sex select according to local son preference.

I then put the theory to a stricter test by examining whether the bulk of the response by poor parents is taking place in regions where, not only is the overall marriage market skewed towards males, but the *difference* between the sex ratio of the wealthy and that of the poor in the marriage market is pronounced. These are the regions in which poor males in the marriage market should experience the greatest difficulty in finding a partner given the steep competition they face from the more numerous and more desirable rich males. Indeed, I find that new poor parents who are observing a marriage market with high economic inequality are precisely the ones who most drastically withdraw their own production of sons. This series of findings offers the first empirical evidence that parental choice is impacted by marriage market prospects and, cumulatively, may be shifting the female population towards

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Daughters, Educate Daughters) campaign launched in 2015).

[7] See Footnote 2. In fact, (Edlund, 1999) demonstrates how a hypergamous caste system with features closely mirroring those of the Indian caste system, in which marriages are endogamous across caste but hypergamous within caste, emerges naturally from her theoretical framework.

[8] (Borker et al., 2018) offers a useful discussion on policy choices in light of stratification by wealth due to the marriage market mechanism; they find that wealth transfers to all women *after* marriage, assuming forward-looking altruistic parents, may be the most effective means of reducing sex selection.

a permanent underclass in regions where sex selection is pervasive.

Having presented evidence that parents internalize the marriage market in their family sex composition decisions, I then explore whether these parental decisions have consequences for the marriage market outcomes of exposed children, particularly the intrahousehold bargaining power of women. To do so, I first present evidence that self-reported ultrasound use, when aggregated at the village level for only first births, can serve as a plausibly exogenous source of variation for parental access to sex selection technology. The endogeneity of skewed sex ratios to the sex preferences of their reference population is a challenge which plagues the existing literature. A region in which sex ratios are heavily male-skewed is likely to be a region where male preference is high, which in turn may be correlated with later life outcomes in favor of males as well. Similarly, the presence of ultrasound technology may be driven by demand for sex selection technology, which may likewise be correlated with later life outcomes. I present evidence that ultrasound access, when proxied by ultrasound use during first births, effectively eliminates the demand component of my variation; I then demonstrate that reported ultrasound use is not correlated with son preference in early childhood outcomes at the individual or village level, suggesting that whatever residual preferences may impact the likelihood of bearing a son at first birth do not manifest themselves in differential later life treatment of sons over daughters.

Armed with this measure of access to ultrasound technology, I verify that the marriage market mechanism is operative only in regions where exercising parental preference over child sex through ultrasound is possible. I show that the entire effect of the poor withdrawing son production in highly competitive marriage markets occurs in regions where ultrasound is available. In regions where it is unavailable, such wealth-stratification of sex ratios in response to a child's anticipated marriage market does not occur.

Finally, I exploit the geographical variation in access to ultrasound, paired with the temporal variation due to import restrictions on ultrasound technology in India prior to 1981, to examine how a family's exposure to sex selection technology affects the later life marital outcomes of their children, and in particular, the intrahousehold bargaining power of their sons' wives.[9] Exposed females (wives) are considered those who were born after 1980 and married to men in regions with high village-level ultrasound exposure. Recall that the channels through which skewed and socially stratified sex ratios at birth may affect intrahousehold outcomes later in life are four-fold. First, the relative scarcity of the female

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[9] I focus on sons' wives rather than daughters because the NFHS only contains data on ultrasound for a woman's village at marriage, and has no data on the woman's natal village. Since the vast majority of women in India marry outside of their natal village (while the vast majority of men remain within their natal village), the ultrasound exposure variation I employ can only be reliably linked to the parental exposure at birth for sons after 1980, not daughters.

raises her price, implying a more desirable match for her. Second, the scarcity simultaneously results in a marriage squeeze (Rao, 1993) where the average man must reach into younger cohorts of females to find a partner. Third, a marriage market affected by endogenous sex selection involves a composition effect which manifests itself in lower quality (in terms of wealth, health, education, etc.) of the average female relative to the average male. Fourth, greater variance in quality across males and females may lead to a more uneven distribution of bargaining power within the marriage. These various channels predict, unambiguously, that the average married woman in an exposed region will be of poorer quality and marry a man more different from her (older and of differentially better 'quality') than her unexposed counterpart. Given the first and fourth channels, however, the direction of her bargaining power within the marriage is *ex ante* ambiguous.

I therefore examine a host of outcomes which describe the compositional, matching, and bargaining mechanisms at play, and I document effects consistent with the model's predictions. Relative to her unexposed counterpart, the exposed female is less educated and in poorer health. Both unconditional and conditional on her quality, the exposed female marries a man who is more different from her: she has a larger education and age gap with her spouse. Finally, her marriage exhibits lower bargaining power in the form of lower age at her first birth, greater consent to abuse, and greater distance from the her ideal family size. These results are robust to a placebo check using an earlier birth cohort that could not have been exposed to ultrasound as well as a two-sample two stage least squares estimation exercise employing data on distance to the nearest health center from an earlier survey round as an instrument for access to sex selection technology.

The remainder of the paper is structured as follows: in Section 2, I present a brief literature review on the links between ultrasound, sex ratios, and bargaining power. In Section 3, I offer a stylized model of parental choice of sex selection in the social context of India. In Section 4, I describe the data employed for the empirical analysis. In Section 5, I proceed with the series of analyses described above. Section 6 presents robustness checks, and Section 7 explores alternative stories and concludes.

2 Literature

2.1 The effect of ultrasound on sex ratios

Ultrasound technology was first introduced to India in 1981. As it became cheaper and more mobile, the technology proliferated rapidly to more rural areas. Hvistendahl (2011) documents how India's aggressive push to decrease fertility in the 1980s, paired with the population's preference for sons, made ultrasound and sex selective abortion particularly attractive innovations. Demand for ultrasound as a sex selection tool was pervasive, as it offered parents a more convenient alternative to controlling the sex composition of their family than the emotionally taxing and socially visible practice of infanticide. Clinics that offered the technology openly advertised its efficacy as a sex selection tool: it was not uncommon in the 1980s and 1990s to find health clinic advertisements of the nature: "Pay 500 rupees today and save 50,000 rupees tomorrow;" with the latter amount referring to the dowry that parents of females must pay to marry their daughters off, and the former referring to the cost of one ultrasound to ensure that parents do not bear daughters (Jacoby, 2010).

The relationship between ultrasound access and skewed sex ratios amongst exposed children is fairly well established in the literature. Chen, Li, and Meng (2013) investigates the effect of ultrasound diffusion on sex ratios in China using data on technological diffusion from thousands of local newspaper clippings (Local Gazeteer) from 1976-1995, demonstrating a robust relationship between the expansion of ultrasound and an increase in the ratio of males to females at birth. Bhalotra and Cochrane (2010) investigate the same relationship in India through a triple difference in which their three control groups are: (1) births that occur pre-ultrasound, (2) births of the first order, and (3) births that occur after the family has achieved its desired sex mix of children (which they identify as one girl and two boys). The authors find that availability of ultrasound in India generated an increase in the sex ratio differentially for children of later birth order in families not yet at their preferred sex mix. Finally, Akbulut-Yuksel and Rosenblum (2012) study the effect of ultrasound diffusion on sex ratios across states in India using aggregated measures of self-reported ultrasound use as their proxy for diffusion. They find a robust positive relationship between ultrasound exposure and sex ratios in states where the technology was first introduced, but no such relationship in states where it was later rapidly diffused.

2.2 The effect of sex selection and skewed sex ratios on bargaining power

Though there are a few oft-cited studies on the relationship between skewed sex ratios and intrahousehold bargaining power, most studies are based in developed countries and none investigate the relationship when skewed sex ratios are endogenously determined by son preference and sex selection.

Contrary to my results, most present literature finds positive impacts of male-skewed sex ratios on female bargaining power. Angrist (2002) studies the effect of skewed (adult) sex ratios on second generation immigrant marriage rates and female labor force participation, employing changes in first generation immigration policies as an instrument for changing sex ratios. In accordance with a story of increasing demand for marriageable females, he finds that higher sex ratios lead to higher female bargaining power in the household and lower female labor force participation. Exogeneity of sex preferences is unclear, as different immigrant populations have strong (and varying) sex preferences that are likely to be passed on from the first to the second generation. Chiappori, Fortin, and Lacroix (2002) employ increases in state level sex ratios as a proxy for increases in female bargaining power, demonstrating that couples in states with higher sex ratios see less female labor force participation and more non-income transfers from husband to wife. Abramitzky, Delavande, and Vasconcelos (2011) investigates the effect of the post-WWII scarcity of French men on marital assortative matching and other marriage market outcomes and finds a similar force at play: scarcity in marriageable men is correlated with men marrying women of relatively higher social class with a smaller age gap and fewer divorces. Lafortune (2013) examines the implications of changes in the marriage market sex ratio on pre-marital investments, and finds that a doubling of the marriage market sex ratio is associated with a 0.5 year increase in educational investment by males, suggesting that individuals anticipate their marital prospects and invest in themselves in order to be sufficiently competitive in their future marriage market. Wei and Zhang (2011) investigate skewed sex ratios in China and find that households with sons in regions with higher sex ratios have significantly higher savings rates than those with daughters and those with sons in lower sex ratio regions. The authors attribute this effect to families seeking to make their sons wealthier and thus more desirable in regions with particularly competitive marriage markets for males. Stopnitzky (2017) finds that men on the marriage market in India are more likely to invest in a toilet, a valuable asset for women, than their non-market counterparts.

Anukriti (2013) offers a valuable contribution to this literature, investigating the impacts of skewed sex ratios in India on pre- and post-marital outcomes for women. The study finds that women born into high sex ratio state-by-year-by caste-religious groups have differentially lower educational attainment, lower age at marriage, a larger spousal age gap, and a lower likelihood of entering the labor force than their low sex-ratio regime counterparts. The results are cumulatively interpreted as reflective of an improvement in women's positions in the marriage market in high sex ratio regimes. The present study engages the same context of changing sex ratios in India since the 1980s but considers the marriage market dynamics across wealth strata in understanding both parental decision-making over the sex composition of their families and the marriage matches that may result.

Beyond their increasing relevance, the stylized fact that sex ratios are often segregated by wealth, paired with Edlund (1999)'s theoretical framework around hypergamy, suggest that the literature has thus far missed this crucial point of departure. Wealth stratified sex ratios that are skewed by parental preference and social norms around marriage (rather than access to the technology or differential son preference alone) predict an *enduring* segregation of sex by wealth: a permanent female underclass. Relative to the world without sex selection, this environment implies a higher variance in quality between the sexes in marriage markets, potentially leading to poorer assortative matching and thus poorer post-marital outcomes. Because females will increasingly lie on the left tail of the quality distribution, female intrahousehold bargaining power relative to that of males may weaken, a prediction in stark contrast to existing empirical findings on the effects of sex imbalance on bargaining power in marriage.[10] [11]

3 A model of sex selection

I present a stylized model of sex selection and ultrasound use adapted from Edlund (1999).

Consider a society with $N >> 0$ parents of childbearing age. N/2 parents are rich (of equally high wealth) and N/2 parents are poor (of equally low wealth). Each parent has preferences over the sex composition of her family and must decide whether or not to employ a sex selection technology to realize such preferences. The set of actions that each parent can take are therefore as follows:

$$A \in \{US_m, US_f, noSS\}$$

where US_m represents the use of ultrasound to select for a male child, US_f represents the use of ultrasound to select for a female child, and $noSS$ represents the use of no sex selection technology.

The cost of ultrasound, which is purely monetary, is C. Both technologies are perfect; in other words, once a fee is paid for the use of a technology, a parent is guaranteed to have a child of the sex she desires.[12] Parents derive utility from children through two means: inherent sex preference and the future marital prospects of the child. As in Edlund (1999),

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[10] Note that Edlund's theory makes a distinction between sex preferences which are 'irrational' (due to prejudice, sexism, traditional allegiances, etc.) versus those which are 'rational' (due to economic pressures to marry). Of course, this line is a blurry one: we may argue that status considerations are equally rational, and perhaps more compelling for the wealthy than the poor. The key exclusion restriction required in our context is therefore: do the underlying motivations behind sex preference also affect the treatment of female adults in the household/in later life outcomes?

[11] A key assumption underlying this mechanism is that parents derive utility from (1) marrying their child off and (2) marrying their child to someone of an equal or higher social status; but they do *not* derive utility from the anticipated bargaining power of that child once married.

[12] Thus the cost of sex selection is the expected present discounted value of all future payments of ultrasound

a married son is preferred to a married daughter and a single son is preferred to a single daughter (i.e. inherent son preference), while a married daughter is preferred to a single son. However, the society is also one in which hypergamy is practiced, making it is socially acceptable for daughters to marry up in social status but unacceptable for daughters to marry down. Preferences for the rich are thus ordered as follows:

$$U(m_{RR}) > U(m_{RP}) > U(f_{RR}) > U(m_R) > U(f_R) > U(f_{RP})$$

and for the poor as follows:

$$U(m_{PR}) > U(m_{PP}) > U(f_{PR}) > U(f_{PP}) > U(m_P) > U(f_P)$$

where $U(m_{RR})$ denotes the utility that a rich parent derives from a son who marries rich, $U(m_R)$ the utility a rich parent derives from a single son, $U(m_{PP})$ the utility a poor parent derives from a son who marries poor, $U(f_P)$ the utility a poor parent derives from a single daughter, and so forth. In accordance with the social standards of hypergamy, $U(f_{RP}) = -\infty$ for simplicity.

Marital prospects of each child are determined in equilibrium. A parent's expected utility from employing (or not employing) a sex selection technology to bear a child of a particular sex is thus a weighted average of the utilities of a married and an unmarried child of the given sex, weighted by the probability of marriage, less the cost of the technology. Denoting $U(s^0)$ as the utility gained from a child of sex s if unmarried and $U(s^1)$ as the utility gained from a child of sex s if married, with $s \in \{M, F\}$, we can write the expected utilities derived from each sex selection technology as follows:

$$U(US_s) = \pi U(s^1) + (1-\pi)U(s^0) - C$$

$$U(noSS) = 0.5[\pi U(f^1) + (1-\pi)U(f^0)] + 0.5[\pi U(m^1) + (1-\pi)U(m^0)]$$

Note that both π, or the probability of the child marrying, and whether $U(s^1)$ represents a marriage between children of the same social strata or different social strata, will be determined in equilibrium.

Appendix Figure 1 presents the complete payoff matrix for all strategies of the rich and the poor. What becomes immediately apparent is that for rich parents, sex selecting for daughters is strictly dominated by no selection or sex selection for sons: if all rich parents sex select for daughters, their daughters will have no male counterparts to marry (since there

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for as many times as needed until the parent bears a child of the desired sex. Since the gender of a child in utero is effectively random and equally likely to be a male as a female, the expected total cost of the technology should be the same across all parents. This is a simplification a la (Edlund, 1999).

are no rich sons and rich daughters cannot marry down); since unmarried sons are strictly preferred to unmarried daughters, the rich will never sex select for females. Likewise, for poor parents, sex selecting for sons is strictly dominated by no selection or sex selection for daughters: if all poor parents sex select for sons, their sons will have no female counterparts to marry (since there are no poor daughters and hypergamy prevents rich daughters from marrying poor sons); since a married daughter is strictly preferred to an unmarried son, the poor will never sex select for sons.[13] Upon eliminating these strategies, we are left with the following payoff matrix, where the columns and first line within each cell represents the strategies and payoffs, respectively, for the poor, while the rows and second line within each cell represent the strategies and payoffs for the rich.

Figure 1. Simplified Payoff Matrix

Poor/Rich	US_f	$noSS$
US_m	$U(f_{PR}) - C$ $U(m_{RP}) - C$	$0.5[U(m_P) + U(f_{PR})]$ $0.5[U(m_{RP}) + U(f_R)] - C$
$noSS$	$U(f_P) - C$ $0.5[U(m_{RR}) + U(f_{RR})]$	$0.5[U(m_{PP}) + U(f_{PP})]$ $0.5[U(m_{RR}) + U(f_{RR})]$

Two pure strategy Nash equilibria emerge: $(U_f{}^{poor}, U_m{}^{rich})$ or $(noSS^{poor}, noSS^{rich})$. Naturally, there will be preference heterogeneity in the population, such that some individuals (both rich and poor) may prefer single sons to married daughters, and mixed strategies may emerge. Though highly stylized, this model captures three key points. First, parental decisions on the sex composition of their children depend on the anticipated (equilibrium) sex ratio in their child's future marriage market. Second, three of the four potential outcomes generate a society where sex ratios are higher amongst the rich than the poor. Third, the poor have differentially lower sex ratios in areas where the rich sex ratio is especially high. In other words, villages will either find themselves in an equilibrium where sex ratios are not differentially skewed across wealth $(noSS^{poor}, noSS^{rich})$, or in an equilibrium where they are inversely skewed ($(U_f{}^{poor}, U_m{}^{rich})$ or any mixed strategy): in places where the wealthy have relatively more sons, the poor withdraw their production of daughters. The larger the male skew among the wealthy, the larger the reduction in males among the poor.

Note that this final prediction of the model is distinct from that of a simpler model of credit constraints for the poor. If the poor are financially restricted from accessing ultrasound technology (the cost of ultrasound is CR for the poor, with $R > 1$), then they may be forced

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[13] Note that this dominant strategy can be weakened (to more closely approximate reality, in which there is evidence that the poor do sex select for sons to some extent) by introducing heterogeneity among the poor in the value they place on marriage. If son preference is sufficiently strong, the poor may then choose to sex select for a son even if he has no future chance of marriage. I refrain from formalizing this complication as the relevant predictions can be derived from the simpler model.

to choose $noSS$ regardless of the strength of their preference for sons. This constraint does indeed predict that the rich exhibit greater male production than the poor. However, it does not predict a differential response by male skewness among the rich: regardless of the child sex ratio among the wealthy, the poor will face a binding credit constraint that permits them, everywhere, the production of the same limited number of sons.

The stratification of sex ratios by wealth, whether due to credit constraints or additionally from the active response of parents to their children's future prospects, has obvious implications for the marriage market of said children. The female in such a market will be drawn from a left-skewed wealth distribution, while the male will be drawn from a right-skewed wealth distribution, yielding a marriage in which the husband is relatively wealthier than the wife. Concomitantly, assuming son preference across all wealth strata, markets in which wealth distributions are skewed along sex are also likely to be markets in which the *average* sex ratio is high. The combined effect of these two channels on the intrahousehold outcomes of a marriage match is ambiguous: while the former channel of wealth disparity may yield lower bargaining power for the female, the latter channel of scarcity should produce the opposite. The question remains an empirical one, and the subject of the latter half of this study.

4 Empirical analysis

4.1 Data

I employ the 2005 wave of the National Family Health Survey (NFHS-III), a survey which draws a representative sample of ever-married women of childbearing age (ages 15-49) across all states of India. The dataset provides detailed information on a woman's pregnancies, including ultrasound use, her child-bearing history, and various measures of intrahousehold bargaining power and intimate partner violence. The sample covers approximately 260,000 children across 3,850 villages (or 'clusters' as determined by the DHS sampling frame).

4.2 Does the marriage market inform parents' fertility decisions?

I first examine whether parents actively internalize a child's anticipated marriage market conditions when determining the sex composition of their family. Following Edlund and Lee (2013), I employ the *present* marriage market as the relevant proxy for a just-born child's future market: imagine a parent-to-be who notices the many unmarried men in her village (see the New York Times series on Gendericide, (NYtimes, 2010)), recognizes which types of individuals are struggling most to find a match, and actively responds to these anticipated costs by adjusting the sex composition of their own (still forming) family.

Loosely following the empirical strategy of Edlund and Lee (2013) in South Korea, I estimate the relationship between the within-family child sex composition of individuals born between 2000-2005 and the village average adult sex composition of individuals born between 1971-1986, all of whom should be either married or eligible for marriage by 2005. In other words, I regress the fraction of male children born in 2000-2005 at the household level on the village level fraction of males in the contemporaneous marriage market:

$$FractionMaleChildren_{hv} = \alpha + \beta FractionMalesMarriageMarket_v + \gamma_{hv} + \epsilon_{hv}$$

The coefficient of interest is β. γ_{hv} is a set of household level controls (education and occupation of respondent and spouse, respondent's age, respondent's religion, whether the household is in a rural area, ultrasound accessibility of the village, the village level sex ratio of children born between 1991-1995, and interactions of each of these variables with the fraction of males in the marriage market). I control for the village level sex composition of children born in 1991-1995 (adolescents not of marriageable age) as a proxy control for village-specific sex preference.[14]

Results are presented in Column 1 of Table 1. The coefficient of interest is negative and significant at the ten percent level, consistent with a setting in which parents internalize marriage market conditions when choosing the sex composition of their own family: where the sex ratio in the marriage market is relatively high, families adjust their child composition in favor of daughters; where the sex ratio is relatively low, families adjust their composition in favor of sons.

I next test the key theoretical prediction of the model: does the nature of the response to the marriage market differ by wealth strata?[15] Interacting the fraction of males in the village marriage market with the wealth strata of the parent-to-be (with "poor" representing those in the bottom two quintiles of the wealth distribution and "rich" those in the top two), Column 2 presents these results.[16] The large and precise negative coefficient implies that the inverse relationship between the sex ratio in the marriage market and that of just-born children is driven entirely by the poor: the poor sex select for sons differentially less in

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[14] The correlation between the village level sex composition of adolescents and that of the current marriage market is 0.007. All results are robust to excluding this control.

[15] (Edlund and Lee, 2013) do not empirically investigate the relationship between birth and marriage market sex ratios differentially across wealth groups nor sex selected regions; their analysis stops at the first specification and includes no control for village-specific sex preference.

[16] Results are robust to (1) defining "poor" as the bottom three quintiles of the wealth distribution and "rich" as the top two, and (2) observing each quintile separately, although the latter estimates are noisy due to the smaller sample size per cell. Results available upon request.

their own family composition when they witness an excess of males in the existing marriage market. To better approximate the relevant marriage market for a given household, I run a stricter specification with caste, religion, and state-by-village-size fixed effects in Column 3. The magnitude of the coefficient increases slightly and remains significant at the five percent level. The strictest specification in Column 4, which includes caste, religion, and village-level fixed effects, maintains the magnitude of the coefficient but is unsurprisingly noisy given the limited number of observations available per village-by-age-cohort cell.

Recall that, in theory, the negative coefficient on the interaction term may simply be due to credit constraints: the poor may be unable to afford ultrasound to the extent that the rich can, making the gap in sex ratios between the rich and the poor larger in regions where ultrasound technology is available (which, in turn, may be positively correlated with the dependent variable of village level marriage market sex ratios). However, the magnitude of the coefficients precludes credit constraints as the sole driver of differential sex selection: the sum of the coefficients on $FractionMalesMarriageMarket$ and its interaction with $Poor$ is also negative, and an F-test between the two confirms their difference. Were binding credit constraints the primary reason behind a lower sex ratio among the poor, one would expect the two coefficients to cancel each other out (regardless of the prevailing village sex ratio, the poor would face an upper bound on the opportunity to sex select). Instead, we see a differentially larger withdrawal in the production of males by the poor when they face an especially unequal marriage market (one with many wealthy males to compete against), suggesting an active *response* to the anticipated marriage prospects of their unborn child.

A back-of-the-envelope calculation offers a lower bound on the magnitude of this active response. For ease of interpretation, Column 5 presents the results from a simple binary difference-in-difference specification with no controls: the fraction of males in the village marriage market is transformed into a binary variable at the median, in which the measure equals one if the fraction of males in the market is greater than 0.524 ("more skewed marriage market") and zero otherwise ("less skewed marriage market"). The coefficient on the interaction is smaller given the absence of variation in marriage market sex ratios beyond the median, but it remains negative and precise. Panel A of Table 2 translates these coefficients into the unconditioned means of child sex ratios for the poor and the rich in villages with more and less skewed marriage markets. The resulting gap in child sex ratios across wealth is 0.024 (2.4 more males for every 100 children among the wealthy than the poor). Panel B then considers a world where credit constraints are binding, which would imply that the child sex ratio of the poor would, in the most conservative scenario in which the poor have zero ability to pay for sex selection technology, remain unchanged across highly skewed and less skewed village marriage markets, while that of the rich would, unrestricted by the cost of ultrasound, increase according to preference. The resulting gap in child sex ratios across wealth is 0.014 (1.4 more males for every 100 children among the wealthy than the poor). This simple exercise demonstrates that at least 40% of the gap in sex ratios between the poor and the rich can be explained by the poor actively responding to the state of the marriage market. The estimates also suggest that the reaction by the poor leads to at least one additional girl per 100 poor girls surviving relative to the counterfactual pure credit constraint world (51.3 males v. 52.3 males per 100 poor children). Importantly, this exercise presents a strict lower bound on the role that an active response by the poor to the anticipated marriage market plays in the wealth differential in sex ratios, as it assumes that the poor are fully credit constrained and therefore can never use sex selection technology. As Appendix Figure 2 shows, approximately ten percent of women in the bottom two quintiles of the wealth distribution report having used ultrasound technology in at least one of their pregnancies, suggesting credit constraints are not binding for the poor.

Taking the theory a step further, I create a measure of the extent to which the village level marriage market is skewed between the rich and the poor. Specifically, I calculate the gap, or difference, between the fraction of marriageable males out of all marriageable individuals within the top two quintiles of the wealth distribution (the "rich") and the parallel fraction of marriageable males in the bottom two quintiles of the wealth distribution (the "poor"). Taking the marriage market mechanism seriously, the larger this gap, the more that poor households should downward-adjust the sex composition of their own family.

$$CohortIIFractionMale_{hv} = \alpha + \beta CohortIFractionMale * Gap * Poor_{hv} + \gamma_{hv} + \epsilon_{hv}$$

The coefficient of interest is β. γ_{hv} is a set of household level controls (education and occupation of respondent and spouse, respondent's age, whether the household is in a rural area, ultrasound accessibility of the village, the village level sex ratio of children born between 1991-1995, and interactions of each of these variables with the fraction of males in the marriage market as well as interactions with the fraction of males in the market by wealth). Caste, religion, and state-by-village-size fixed effects are included.

Results are presented in Table 3. As expected, the coefficient on the triple interaction of interest is negative and significant: poor households in villages with not only a higher sex ratio in the total marriage market but also a larger gap in sex ratio between the rich and the poor in the marriage market (with the rich bearing significantly more boys) appear to be the key subset to react to marriage market conditions by reigning in their own relative production of boys.

Taken together, these results demonstrate that parents are indeed considering future marital prospects when determining the sex of their unborn child. That we see this behavioral response only amongst poor families offers compelling support for Edlund's 1999 hypothesis: while wealthy families have an incentive to sex select in favor of males (thus co-moving their child sex ratio with the existing skewed marriage market sex ratio), poor families can only respond to such increases in wealthy males by adjusting their sex composition away from sons.[17]

There are two caveats to this discussion. First, we might be concerned about the endogeneity of the marriage market variable: villages of a certain type may both draw more young marriageable men to the village and have families with certain son preferences. For example, regions with labor markets that have high returns to male participation may encourage the production of males. Although plausible, this endogeneity would bias the coefficient of interest upwards, implying that presented estimates are lower bounds on the true response. It is more difficult to craft an endogeneity story that moves in the opposite direction. Perhaps in labor markets where females complement males but the initial work is male oriented (eg. construction of factories which will eventually employ women), poorer families, upon seeing the presence of many male workers, may anticipate increased labor market returns for females and thus bear more daughters in villages with a large proportion of males currently in the labor [and thus marriage] market. If ultrasound accessibility is correlated with other characteristics that make a village amenable to factory construction (which is not unlikely - closer to a city, more electricity, etc.) then I may be misattributing the observed negative coefficient to parental responses to the marriage market rather than parental responses to the labor market. Note that this only applies to men who were born in the village; the estimating sample does not include men who have migrated into the village for labor, making most labor market stories less likely. Nonetheless, I offer a rough test by running the following regression:

$$\begin{gathered} CohortIIFractionMale_{hv} = \\ \alpha + \beta_1 CohortIFractionMale_v + \beta_2 CohortIFractionMale_v * ManualWork_{hv} + \\ \delta ManualWork_{hv} + \gamma_{hv} + \theta_j + \epsilon_{hv} \end{gathered}$$

where *ManualWork* is a binary variable which equals one if the respondent's spouse is involved in skilled or unskilled manual work. Though coarse, it is the NFHS classification most closely approximating construction or factory work. Results are available upon request; the coefficients on both *ManualWork* and *CohortIFractionMale*ManualWork* are noisy and close to zero.

Second, the relevant marriage market in this context may not be the village; anecdotal evidence (NYtimes, 2010) suggests that there is frequent cross-village communication and

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[17] This does not necessarily mean that the poor sex select in favor of daughters, but rather that they sex select to a lesser degree than the rich in favor of sons.

intermarriage, especially when there is a dearth of the demographic in demand (eg. marriageable women) in ones own community. Unfortunately, due to limitations in my data, I am unable to identify neighboring villages and thus cannot expand the reach of the marriage market sex ratio to its most representative radius. Arguably, any endogenous parental response to the small village level marriage market would only be exacerbated if extended to the more relevant broader marriage market.

4.3 Ultrasound use as proxy for past access to sex selection technology

Having offered a series of results consistent with parental internalization of a child's future marital prospects, I now explore whether such endogenous sex selection at birth, made possible through the availability of ultrasound, had implications for exposed children's realized marriage markets. To do so, I first construct a measure of access to sex selection technology.

The NFHS-III includes a detailed module on antenatal care during pregnancy and after birth for women who report having been pregnant in the last five years prior to the survey (2000-2005). In this module, women who report having received antenatal check-ups during their pregnancy are asked whether they ever used an ultrasound in the checkup. This study's question of interest would be ideally answered with ultrasound access data from 1981-1989, which is the cohort of births just entering the marriage market in the 2005 NFHS-III. However, no publicly available dataset exists with detailed information on ultrasound access in India for this time frame. The next few sections endeavor to make the case that a derivative of ultrasound use in 2000-2005 is a valid proxy for ultrasound access among my population of interest.

I construct an "ultrasound exposure" variable by calculating the village-level averages of reported ultrasound use among first births between 2000-2005. I focus on first births as the literature has established that parents are unlikely to sex select in their first births (Hu and Schlosser, 2015; Bhalotra and Cochrane, 2010). Figure 3 of the Appendix reifies this phenomenon within the context of ultrasound use: parents are considerably more likely to bear a son, conditional on having used ultrasound, in later births; at first birth, there is no statistically significant relationship between using ultrasound and bearing a son. Figure 3 elucidates two important features of the ultrasound measure available in the NFHS: (1) Self-reported use of ultrasound is a true proxy for actual ultrasound use in a village, since use is correlated with sex selection (i.e. on average, respondents do not hide the fact that they used a sex selection technology); and (2) Ultrasound is being used to sex select, but not necessarily by families who have a strong preference for sons. Rather, it is being used by families who have (by chance) an 'excess' number of daughters and have not reached their ideal family sex composition (a la Jayachandran (2017); Gupta and Bhat (1997); Visaria (2005); Bhalotra and Cochrane (2010); Anukriti, Bhalotra, and Tam (2018)). A focus on first births thus minimizes the demand-side endogeneity inherent in a cross-birth ultrasound exposure measure. A village-level aggregation of first birth ultrasound use further eases demand-side endogeneity by exploiting cross-village, rather than cross-individual, variation in ultrasound.[18]

The distribution of the village level average ultrasound measure, as shown in Figure 4 of the Appendix, is left-skewed: the median (mean) village has 16% (21%) of respondents reporting ultrasound use at first birth, and 28% of villages contain no respondent who reports ultrasound use at first birth.

Ultrasound exposure is nonrandomly distributed across villages (Table 4). Individuals who live in villages with higher levels of ultrasound exposure are less likely to be rural residents, are wealthier and more educated, and have spouses with more professional occupations. These correlations are not surprising: ultrasound technology arrived first to city centers and major health institutions and proliferated outward from there.

4.4 Effects of ultrasound exposure on child outcomes

Despite the nonrandom distribution of exposure, village-level ultrasound use in 2000-2005 is an exogenous measure of access to prenatal sex selection technology in the 1980s if, conditional on observables, average self-reported ultrasound use is correlated with access to ultrasound and only impacts later-life outcomes through this access channel.

In order to address this demand-centered endogeneity concern, I examine the relationship between ultrasound exposure and early childhood outcomes. If aggregate village-level ultrasound exposure is correlated with later life marital outcomes through an underlying parental son preference, such son preference should first manifest itself in parental investments in their offsprings' early life outcomes.

Several recent papers have explored the relationship between the 'wantedness' of a child and early childhood outcomes (Almond, Li, and Meng, 2014; Hu and Schlosser, 2015; Shepherd, 2008; Anukriti, Bhalotra, and Tam, 2018). The present analysis closely follows that of Almond, Li, and Meng (2014), which investigates the impact of access to ultrasound on early childhood investments in China. Building on Chen et al.'s analysis of the impact of ultrasound on sex ratios, Almond and coauthors posit that, if sex selection is driven by strong

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[18] This village-level aggregation replicates the technique pioneered by Geppert, McClellan, and Staiger (2000) to eliminate patient-level demand-side endogeneity in health outcomes by aggregating treatments at the hospital, rather than patient, level.

son preference, parental investments in children after birth should move in a predictable direction. Namely, assuming that ultrasound diffusion is not determined by individual preferences, postnatal investments in girls should increase in areas with high diffusion, since parents who choose to bear daughters in such regions (where access is plentiful) must be selected to have relatively lower son preference than their son-bearing counterparts. The direction of prenatal investments, however, is ambiguous: if pregnancies are carried to term, ultrasound can allow for in utero gender discrimination against girls. However, if the child is aborted, one would expect an increase in in utero investments in girls through the same preference sorting mechanism operating in postnatal outcomes.

Almond, Li, and Meng (2014) find no effect of ultrasound access on differences in postnatal investments across sexes. However, they do find that early neonatal mortality increases for girls relative to boys in areas with ultrasound access, which they argue is likely a result of decreased in utero investments in girls relative to boys. The analysis suggests that, while parents' sex selection decisions are motivated by son preference, these preferences no longer manifest themselves conditional on the birth of the child.

Hu and Schlosser (2015) run a similar exercise in the Indian context employing multiple rounds of the NFHS data used in the present study. They exploit time and state-level differences in the sex ratio at birth, their proxy for parental access to sex selection technology, interacted with whether the child is female. They find that higher sex ratios are associated with lower rates of stunting and malnutrition for girls relative to boys, but find no change in girls' mortality or respondents' stated son preference.[19]

I perform a similar exercise with a few key adjustments: first, I employ the village-level average of reported ultrasound use rather than the sex ratio at birth as my proxy for parental access to sex selection technology. The sex ratio at birth captures variation only in the degree to which parents use ultrasound for the purposes of selection. The ultrasound measure arguably casts a wider net on access, since both parents who do and do not employ ultrasound for selection report using the technology. Insofar as this is an exercise in validating the ultrasound exposure measure as a proxy for parental *access* to sex selection technology, it is sensible to focus on ultrasound use rather than sex ratios at birth for the present exercise.[20] My second difference stems from the focus on ultrasound at the village level: because NFHS

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[19] Anukriti, Bhalotra, and Tam (2018) find similar results using a different strategy: they pair temporal variation in ultrasound availability in India with the birth order of the child and mother fixed effects, and find that ultrasound technology access increases vaccinations and breastfeeding among daughters relative to sons.

[20] Note that this is in contrast to the objectives of existing literature in this vein (Hu and Schlosser, 2015; Anukriti, Bhalotra, and Tam, 2018). While they exploit parental preferences that determine prenatal sex selection, I aim to identify a measure of access to prenatal sex selection technology which is not endogenous to parental preferences.

datasets cannot be linked at the village level over rounds, I limit my analysis to the NFHS-III only. Third, I focus only on first births for reasons discussed earlier.

The NFHS contains detailed information on prenatal (ultrasound use) and postnatal investments in children only for those born in the last five years, so I restrict my sample accordingly.

To better understand the parent-child dynamics in play, I first run the following simple regression at the mother level, separately for male and female children:

$$ChildInvestment_{ihv} = \alpha + \beta Ultrasound_{hv} + \gamma_{ih} + \theta_v + \epsilon_{ihv}$$

in which *Ultrasound* is the household-level report of whether the mother used an ultrasound in her most recent pregnancy, and the outcome variable *ChildInvestment* for child i in household h in village v spans both postnatal investments such as breastfeeding and vaccinations as well as proxies for prenatal investments such as the size of the child at birth and weight and height at the time of surveying. The standard set of controls γ_h are included (religion, age of mother, age of child, wealth index, education, and occupation) as well as village fixed effects θ_v.

The selection concerns underlying this regression are precisely what I wish to capture: do mothers who report using ultrasound and bear a son display different childcare behaviors than mothers who do not report using ultrasound and bear a son? A daughter? Any difference in child outcomes by ultrasound use may be due to a host of reasons (mother is more prone to pregnancy complications, has more maternal care knowledge, is more cautious or risk averse, or has strong underlying sex preferences). If there is no clear relationship between ultrasound users and child outcomes, then selection on underlying sex preferences as captured in the ultrasound self report is an unlikely channel for affecting later life child investments.

Results are presented in Table 5. Mothers reporting ultrasound use in their first birth put their children (both sons and daughters) to breast at a later hour and for shorter durations. Children borne to such mothers are no more likely to receive a post natal check or vaccinations or be of a different size at birth. These results suggest that demand for sons or daughters and the consequent use of ultrasound does not inform, insofar as ultrasound use at first birth captures, how the user treats her children.

I next replicate the experimental strategy of Almond, Li, and Meng (2014) with the following regression:

$$ChildInvestment_{ihv} = \alpha + \beta_1 Male_{ihv} + \beta_3 Male_{ihv} * UltrasoundExp_v + \gamma_{ih} + \epsilon_{ihv}$$

in which *UltrasoundExp* is a continuous variable of village-level averages of reported ultrasound use at first birth between 2000-2005. The standard set of controls γ_{ih} are included (religion, age of mother, age of child, wealth index, education, and occupation).

Results are presented in Table 6. Panel A presents the specification with mother fixed effects: variation is thus drawn from brothers and sisters within a family across villages of varying ultrasound exposure. Male children experience no differences in early childhood outcomes relative to their female siblings in ultrasound-exposed villages, suggesting that the measure of village level ultrasound use at first birth does not track parental selection or demand effects of ultrasound use on child outcomes.

Panel B replicates the regression with village level fixed effects, as our final specification on later life outcomes exploits this cross-household, rather than cross-sibling, level of variation. Male children are put to breast at a later hour and have a higher likelihood of anemia than female children in ultrasound-exposed villages. These results are substantively consistent with the findings of Hu and Schlosser (2015), potentially reflecting the 'wantedness' of the child.[21]. Across the measures, there is no evidence that males children are treated differentially better than females in ultrasound exposed regions.

4.5 Marriage market mechanism by ultrasound

Making our way to the effects of ultrasound exposure on later life marital outcomes and armed with this measure of access to sex selection technology, I briefly revisit our first set of analyses around the parental internalization of the marriage market. I replicate the most stringent test of the theory along the margin of ultrasound access: that the poor should respond (by withdrawing their production of boys) differentially more in more competitive marriage markets (i.e. those with differentially more rich males competing against poor males). This effect should only arise in regions where families are better able to control the sex composition of their family through ultrasound. Column 1 of Table 7 replicates the main result (presented in Table 3). Columns 2 and 3 present the same results for households in villages with ultrasound exposure below and above the median, respectively. As predicted, the entire effect of the gap in males across wealth strata emerges from those regions that have access to ultrasound technology.

I note that the preceding exercises on marriage market internalization explore the decisions of parents who are, at the time of the 2005 survey, bearing children and forming a family. The final question of interest, however, concerns children who, at the time of the survey, are of marriage age. For this cohort, parents would have made the sex selection decision long ago. I cannot run the direct test of marriage market internalization on this population of parents because, at the time of bearing the children in the sample, the marriage market

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[21] If we consider this channel, our demand side endogeneity concerns will yield *underestimates* of the true effect of ultrasound exposure on later life outcomes: villages with high levels of ultrasound exposure are likely to treat surviving female children better, relative to male children, than those with low exposure

that parents may have used as a proxy for their child's future market had not been exposed to ultrasound. The introduction of ultrasound had only just occurred, so wealth-stratified sex selection by such parents would have had to be driven by a combination of anticipatory motives and credit constraints. Did such differential selection occur among this earlier generation of parents? I investigate the evolution in sex composition for this earlier generation of parents among the poor and the non-poor across villages of varying ultrasound exposure.

I run the following specifications in which my sample is restricted to all children born between 1976-1989 (the relevant marriage market years) as of 2005:

$$RichFractionBoys_{ivt} = \\ \alpha + \beta_1 UltrasoundExposure_v * BornPost1980_t + BornPost1980_t + \gamma_v + \epsilon_{vt}$$

$$PoorFractionBoys_{ivt} = \\ \alpha + \beta_2 UltrasoundExposure_v * BornPost1980_t + BornPost1980_t + \gamma_v + \epsilon_{vt}$$

$$Gap_{ivt} = \alpha + \beta_3 UltrasoundExposure_v * BornPost1980_t + BornPost1980_t + \gamma_v + \epsilon_{vt}$$

where $UltrasoundExposure_v$ is a binary variable equal to one if the village has positive ultrasound exposure at first birth and zero otherwise (equivalent to that of Table 7). $RichFractionBoys_{ivt}$ is defined as the leave-self-out fraction of males who are rich out of all rich children of marriageable age by 2005 in the village (i.e. the sex composition of rich children that each child i is facing), separately calculated for those children born prior to the availability of ultrasound technology (1976-1980) and those born after (1981-1989), $PoorFractionBoys_{ivt}$ is the analogous sex composition of the poor, and Gap_{ivt} is the difference between the two, equivalent to the "gap" of the prior analysis of Table 7. γ_v represents village fixed effects. If wealth stratified sex selection by parents emerged immediately after the availability of ultrasound technology, β_3 should be positive: the poor should bear differentially fewer males relative to the wealthy in villages and cohorts exposed to sex selection technology.

Results are presented in Appendix Table 1. As expected, wealthy families raise their production of males in exposed villages after 1980 (Column 1, though noisy), poor families withdraw their production of males (Column 2, significant at the ten percent level), and the gap between the proportion of males among the wealthy and the poor increases (Column 3, significant at the ten percent level).[22] The results suggest that even as far back as 1981, soon

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[22] It is worth stressing that the strong and significant relationship with ultrasound access arises amongst poorer families rather than wealthier families, again suggesting that the behaviors we observe cannot be driven purely by credit constraints. A credit constraints story would suggest that in regions where ultrasound is available, wealthy families will use it readily (boosting their production of males) while the poor will be unable to afford the technology and remain unchanged in their production of males. Instead, we see that in regions where ultrasound is available, poor families reign in their relative production of boys.

after ultrasound was introduced, parents were differentially sex selecting the composition of their family based on their socioeconomic position, potentially due to the anticipation of their unborn child's future marital prospects.

4.6 Effect of ultrasound exposure on marital and intrahousehold outcomes

Having presented evidence that parents internalize the marriage market in their family sex composition decisions, constructed an exogenous measure of access to sex selection technology, and confirmed that sex selection technology is differentially employed by wealth strata, I now turn to the final question of this study: how does a family's exposure to sex selection technology affect the later life marital outcomes of their children, and in particular, the intrahousehold bargaining power of exposed females?

Recall that the channel through which skewed and socially stratified sex ratios at birth may negatively affect intrahousehold outcomes later in life is three-fold. First, skewed sex ratios in favor of males implies a larger number of unmarried males for a given pool of females, which may lead to men reaching into younger pools of women in search of a spouse (or alternatively, men marrying at older ages); second, a marriage market affected by endogenous sex selection involves a composition effect which manifests itself in greater variance in wealth across males and females, which, third, may lead to poorer match quality in terms of socioeconomic background even within a narrow age range. These three channels compete against the standard supply and demand channel: more skewed sex ratios imply that women, being scarcer, should be more valued in the marriage market.

I employ BMI, weight, height, and education as measures of the 'quality' of the married woman, or a proxy for her wealth prior to entering the marriage. We test the theoretical prediction that the average male in a high ultrasound region is marrying a woman of relatively 'poorer quality' than the average male in a low ultrasound region.[23] Note that, although I control for the wealth of the household in all figures and regressions to follow, this wealth control is a closer proxy to the wealth of the husband, and so we should expect to see effects of ultrasound on proxies for pre-marital female wealth despite (or rather, given) the inclusion of this control.

Conditional on this change in the composition of marriageable women, I then estimate the impact of being born in an ultrasound regime on various measures of female bargaining power within a marriage. I examine the outcomes of marriage age, marriage age gap between

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[23] Recall that, as demonstrated in Tables 1 and 3, poor families in high ultrasound regions react more, or bear differentially more females than their counterparts in low ultrasound regions when compared to the wealthy families in each region.

husband and wife, physical abuse, autonomy, age at first child birth, and the number of years between marriage and first birth. The age metrics are commonly used in the literature as proxies for bargaining power; I take advantage of the unique domestic violence module of the NFHS to supplement these with direct measures of intrahousehold dynamics such physical abuse, tolerance of beating, and lack of autonomy. Finally, the number of children and the fraction of male children borne by the respondent demonstrate the intermediate effects of ultrasound: firstly as a pregnancy health tool (leading to lower infant mortality and thus more children) and secondly as a sex selection tool. The number of children borne may also be a measure of bargaining power through the contraception channel, as women with lower bargaining power likely have less control over their own fertility decisions. To measure the extent of this effect, I compose an additional outcome measure of the distance between the respondent's stated ideal family size and her actual family size (subtracting the latter from the former).[24]

4.7 The evolution of sex selection technologies

I exploit the development of prenatal sex selection technologies over the late 20th century and establish 1981 as the first year in which ultrasound began its widespread dissemination in India. Use of prenatal technologies employed for the purpose of sex selection was first documented with amniocentesis techniques in India in 1975 (Sudha and Rajan, 1999). While amniocentesis was developed to detect fetal abnormalities, most couples seeking the test in the late 1970s and early 1980s wished only to learn the sex of their foetus; among the 11,000 couples who volunteered for the test at the All India Institute of Medical Sciences, most women who had two or more daughters and learned that their expected child was female proceeded to have an abortion (Chhachhi and Satyamala, 1983; Ramanamma and Bambawale, 1980; Madan and Breuning, 2014). With the onset of economic liberalization and the easing of import restrictions across the nation in 1981, the cheaper and more portable sex selection technology of ultrasonography entered the Indian market, making fetal sex selection more easily accessible to poor and rural communities. The cost of ultrasound, estimated at Rs. 500 to Rs. 1000, was high but not prohibitively so, especially relative to the future cost

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[24] I draw from a wealth of literature that employs these measures as proxies for intrahousehold bargaining power. Among them, see Bloch and Rao (2002); Aizer (2010); Roy Chowdhury, Bohara, and Horn (2018) for physical abuse and tolerance of beating; Field et al. (2019); de Mel, McKenzie, and Woodruff (2009); Ashraf (2009) for autonomy; Field and Ambrus (2008) for age at marriage; Chari et al. (2017); Miller (2010) for age at first birth; Grossbard-Shechtman and Neuman (1988); Mabsout and van Staveren (2010) for marital age gap; Ashraf, Field, and Lee (2014); Rasul (2008); Doepke and Kindermann (2019) for number of children; and Sun and Zhao (2016); Qian (2008) for child sex ratio; and Jayachandran (2017) for distance between ideal and actual family size.

of a daughter's dowry (Sudha and Rajan, 1999).[25] Private clinics advertising ultrasounds as a sex determination tool were documented in newspapers at least as early as 1982 (Jeffery, Jeffery, and Lyon, 1984) (private clinics had already been offering amniocentesis as a sex selection service in the late 1970s (Ahluwalia, 1986)). Vishwanathan (1991) documents newspaper reports of mobile sex selection clinics, which offered ultrasound services and abortion if desired, in small towns in Haryana by the mid-1980s; farmers came from remote regions to avail themselves of the service. Amniotic fluid samples would likewise be sent from remote districts, which otherwise lacked basic infrastructure, into towns for testing via such mobile clinics (Menon, 1996).[26]

So rapidly were these technologies adopted for the purpose of sex selection that, between 1977 and 1985, Indian federal and state government departments received three mandates establishing the use of prenatal sex determination for the purpose of abortion a penal offense (Kulkarni, 1986). By 1984, the Forum Against Sex Determination and Sex Pre-selection (FASDSP) was established to monitor abuse of the technologies and ensure enforcement of the law. Despite this and a series of increasingly stringent legal restrictions against abuse of such technologies (Sudha and Rajan, 1999), ultrasound [use and misuse] continued to expand with an acceleration of trade reforms in 1991 and General Electric and other multinationals facilitating local production in the years thereafter (Bhalotra and Cochrane, 2010).

Given the available documentation on sex selection services, I establish 1981 as the first "post-ultrasound" year: the year that the ultrasound sex selection technology, being more mobile and affordable than amniocentesis, became available on the Indian market.[27] I argue that, controlling for observables, the village average of self-reported first birth ultrasound use between 2000-2005 has no effect on the contemporaneous marriage market and intra-household dynamics except through its relationship with village-level ultrasound access after 1980. For a view of potential differential trends across villages, Figure 1 presents a series of graphs plotting the coefficient of interest, β_t, from the following specification:

$$LaterLifeOutcome_{ivt} = \alpha + \sum_{t=1973}^{1989} \beta_t UltrasoundExp_v * BirthYear_{ivt} + \gamma_{iv} + \theta_v + \delta_{st} + \epsilon_{ivt}$$

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[25] Using reports from the FASDSP and Saheli Women's Resource Centre, (Menon, 1996) documents landless laborers and sharecroppers who, in the early 1980s, took out loans to pay for such tests.

[26] As Sudha and Rajan (1999) describes, "Grassroots workers and concerned medical practitioners have observed an increase in female foeticide in all segments of society in rural Bihar state, especially after sonography techniques became common. Unscrupulous doctors identify the sex of the child, and provide abortion if it is female."

[27] Bhalotra and Cochrane (2010) define 1985 as their first "post-ultrasound" year using nonparametric plots to identify the break-point in average sex ratios at birth in India. I avoid the use of sex ratios to determine the relevant break-point as it is both a mechanism and outcome in my proceeding analyses; importantly, Edlund (1999) does not predict large aggregate shifts in the sex ratio, given the differential responses by wealth strata. While documentation on amniocentesis use for sex selection would suggest an earlier (1978-1980) break point (Jeffery, Jeffery, and Lyon, 1984), I use 1981 as a middle ground: the first year ultrasound technology entered the Indian market.

where $UltrasoundExp_v$ is a continuous variable of village-level averages of reported ultrasound use, $BirthYear_{ivt}$ is a dummy variable indicating whether individual i in village v was born in year t, γ_{iv} represents a set of individual level controls (wealth index, religion, age, education, occupation, spouse's education, spouse's occupation), θ_v is village fixed effects, and δ_{st} is state by year fixed effects. For bargaining power outcomes, I include in γ_{iv} controls for BMI, weight, and height in order to examine bargaining outcomes conditional on compositional changes.

Note that the outcomes are measured in 2005 but plotted along the birth year cohort dimension (so individuals born in 1980 are 25 years old when reporting the outcome of interest). If my identifying assumption holds, then, controlling for relevant observables, trends in the outcome should be comparable across all birthyears prior to 1981 (when ultrasound was not available in India and could thus not affect the later marriage market) and should diverge according to ultrasound access gradually from 1981 onwards.

Figure 1 presents the trends for outcomes on composition. Both BMI and weight follow comparable trends in the 1970s but exhibit a drop amongst exposed females in the 1980s. Education also maintains comparable trends across regions of varying ultrasound exposure prior to 1981 but decreases differentially in more exposed regions after. Height measures exhibit large fluctuations and no discernable pattern in the 1980s.

Figures 2 and 3 present the trends for outcomes on matching and bargaining, respectively. While the education gap trend is noisy, the marriage age gap clearly increases after 1980 amongst exposed females. This is concurrent with a decrease in the average marriage age of female cohorts born after 1980 in exposed regions. The average age of a woman at her first child birth also decreases after exposure, and tolerance for beating, the number of children, and the distance from the respondents ideal family size show marked increases after 1980.

4.8 Primary difference-in-difference specification

Tables 8-10 present the difference-in-difference regression analog:

$$LaterLifeOutcome_{ivt} = \alpha + \beta_1 UltrasoundExp_v * BornPost1980_{ivt} + \gamma_{iv} + \theta_v + \delta_{st} + \epsilon_{ivt}$$

where $UltrasoundExp_v$ is a continuous variable of village-level averages of reported first birth ultrasound use, $BornPost1980_{ivt}$ is a binary variable indicating whether individual i in village v was born after 1980, γ_{iv} represents a set of individual level controls (number of antenatal visits, wealth index, religion, age, education, occupation, spouse's education, spouse's occupation), θ_v is village fixed effects, and δ_{st} is state by size of village by year fixed effects. The latter makes this an exacting specification: any parallel time trends that may be conflated with the trends in ultrasound exposure would have to be occurring across villages with high and low ultrasound exposure, but within villages of similar size within the same state. In order to limit selection effects, I limit the sample to married women born between 1976 and 1987, though results are robust to extending the time frame in both directions and available upon request.

Table 8 presents outcomes on composition, or the 'quality' of the female. Women born in or after 1981 in villages with higher ultrasound exposure have significantly lower BMI and weight and are less educated than their counterparts. They appear, however, to also be significantly taller than their unexposed counterparts. This result is consistent with ultrasound technology eliminating the need for postnatal discrimination, implicitly raising the 'wantedness' of surviving girls and early parental investments (Hu and Schlosser, 2015; Bhalotra, Chakravarty, and Gulesci, 2020).[28] Height is a stock measure, reflecting an accumulation of parental decisions during an individual's early childhood, while weight is a flow measure, reflecting more recent nutritional status (Duflo, 2000; Martorell and Habicht, 1986). This definitional distinction is consistent with a context of poorer households who chose to bear daughters, and therefore 'want' them more than households who were unable to sex select away unwanted daughters: early investments by such poor parents in behaviors such as breastfeeding raise adult height of their daughters, but persistent scarcity of resources given their wealth level should lower adult weight. Given the diverging directional effects of height and weight, it is also useful to direct attention to BMI as a net measure.

To examine whether this change in the composition of males and females is manifested in the marriage match, I run the following regression:

$$HusbandEducation_{ivt} = \\ \alpha + \beta_1 UltrasoundExp_v * BornPost1980_{ivt} * WifeEducation_{ivt} + \gamma_{iv} + \theta_v + \delta_{st} + \epsilon_{ivt}$$

I can examine matching by quality solely along the education dimension because education is the only pre-marriage proxy for quality that is available for both husbands and wives in the NFHS. Results are presented in Table 9. The coefficient on the triple interaction is negative and statistically significant: women with lower education in exposed regimes are married to relatively more educated husbands than their counterparts in unexposed regimes.

Table 10 presents results for bargaining power and intrahousehold dynamics, controlling for compositional changes. I find that exposed wives marry earlier, have a larger age gap with their husbands, report higher tolerance for beating in their marriage, have their first child

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[28] Bhalotra, Chakravarty, and Gulesci (2020) offers a useful converse context: they find that female cohorts exposed to a positive shock in dowry prices at birth are significantly shorter in adulthood than their unexposed counterparts, suggesting that parents discriminated against their daughters after birth in places where they anticipated having to pay a high dowry for their daughter.

at an earlier age (a partially mechanical result of getting married earlier), have a shorter interval between marriage and first birth, and bear significantly more children than their stated ideal. Exposed women also have significantly larger families, perhaps consistent with the primary purpose of ultrasound as a maternal health tool (though more likely to be a reflection of lower bargaining power over fertility decisions), and a larger fraction of male children, consistent with the continued use of ultrasound to exercise son preference.

5 Robustness Checks

5.1 Selection on observables

In order to establish an upper bound on the extent to which observed effects in the difference-in-difference specification may be driven by selection, I draw from Altonji, Elder, and Taber (2005), who develop a method of assessing the amount of selectivity bias in an estimate (I closely follow the adaptation by Bellows and Miguel (2009). I construct the ratio of the selection on unobservables to the selection on observables that would be necessary to attribute the entire estimated effect to selection bias. Given a rich enough set of controls, a large ratio implies that it is implausible that the estimated effect can be fully explained away by unobserved selection.

I define unobservables to be the underlying sex preferences of individuals and/or alternative village-specific time trends that can impact the later life outcomes of exposed children. For each of my later life outcomes of interest, I calculate the following ratio, where $\hat{\alpha}$ represents the coefficient on *UltrasoundExp*BornPost1980* in a regression with and without controls:

$$SelectionRatio = \frac{\hat{\alpha}_{controls}}{\hat{\alpha}_{controls} - \hat{\alpha}_{nocontrols}}$$

The ratio for marriage age gap is 7.88; for marriage age, 2.76; for beating, 2.14; for lack of autonomy, 1.4, and for age at first birth, 13.25. All others are less than one. To interpret, a ratio of 7.88 implies that village-specific differential time trends must influence the marriage age gap 7.88 times more than the full set of observable controls in order to attribute the entire estimated effect to selection bias. As a benchmark, Altonji, Elder, and Taber (2005) regard a ratio of 3.55 as strong evidence that unobservables are unlikely to explain away their entire effect.

5.2 1970 Placebo

To further probe the possibility of village-specific time trends, I conduct a placebo check by imposing the identical specification upon the sample of married women born between 1966 and 1975, with treated women denoted as those born after 1970 in higher ultrasound villages (as of 2005). Given that ultrasound was not available in India during this time period, I should see no effect of the ultrasound and birth cohort interaction on my outcomes of interest. Results are presented in Tables 11 and 12, by composition and bargaining outcomes respectively. Estimates on composition outcomes are small and statistically insignificant, although 'exposed' women appear to be better educated. Consistent with this, marriage age, age gap, age at first child birth, and the interval between marriage and first birth are differentially higher for wives in 'exposed' villages after 1970. These patterns may be driven by underlying differences in the wealth of villages with varying [future] ultrasound access; however, the coefficients move in the opposite direction of what is predicted by the selection on sex-preference story.[29]

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[29] This test is particularly important in light of an important paper by Bhalotra, Chakravarty, and Gulesci (2020) on the effect of dowry prices on son preference in India. Among other tests, they exploit a shock to the world commodity price of gold in February of 1980 to demonstrate how an exogenous rise in the cost of dowry (often demanded in weight in gold) led to higher neonatal mortality for girls, presumably due to the higher anticipated marriage cost of bearing a daughter. Given the similar timing of the gold shock and the introduction of ultrasound technology in 1981, we may worry that the latter is simply a proxy for the former: that is, villages with high ultrasound exposure at first births (as measured in 2000-2005) are also villages where the shock in gold prices in 1980 may have been the largest. This may be a concern if, for example, these villages have the highest latent demand for sons: in such villages, standards for dowry (a proxy for the value of a husband) may be highest, and demand for ultrasound may also be highest. The negative effects on the marital outcomes of women estimated in this paper may then be due to parental neglect or distaste for women in regions where they have formed expectations that the cost of their marriage will be high.

The evidence presented on child outcomes offers the first rebuttal to this concern: high ultrasound exposure villages do not treat their sons any better than their daughters, neither within families nor across families. One may still worry that the evidence on child outcomes is contemporary, while the dowry shock and initial ultrasound exposure are historical: perhaps these villages *used* to have high son preference, resulting both in a large dowry shock and higher demand for ultrasound technology. In this case, however, the above placebo check should fail; these regions should also be treating their women poorly prior to 1981. In contrast, "exposed" women prior to 1981 appear to be considerably better off in marriage: they have smaller age gaps in marriage, older age at marriage, older age at first birth, a larger interval between marriage and first birth, and no reported differences in tolerance for abuse or autonomy. Lastly, Bhalotra, Chakravarty, and Gulesci (2020) find that women who were exposed to the gold shock at birth and survived are significantly shorter in height than their unexposed counterparts, consistent with a story of postnatal discrimination. In contrast, Table 8 shows that women in high ultrasound exposure regions after 1980 are in fact *taller* than their counterparts, despite their lower weight and BMI, consistent with the Hu and Schlosser (2015) result on 'wantedness' of surviving daughters in a world of prenatal sex selection.

5.3 Two sample 2SLS: Access to a major health facility

I run a two sample two-stage-least-squares estimation using NFHS-II (1994-1999) data and access to a major health facility as my instrument. Access to a major health facility is a sensible instrument, being correlated with access to ultrasound but otherwise plausibly exogenous to sex preferences (controlling for observables). Additionally, as the second and third rounds of the NFHS lack detailed geographical information, I cannot link the two surveys at the village level and thus cannot directly link ultrasound exposure measures from 1999 (which would be a less distant proxy for access to ultrasound post-1980) with marriage market outcomes from 2005. Using the two sample 2SLS allows me to employ a proxy measure for ultrasound access in 1999 and link it to marital outcomes in 2005.

I run the following reduced form regression on the NFHS III dataset:

$$LaterLifeOutcome_{ivt} = \alpha + \beta_1 UltrasoundExp * BornPost1980_{ivt} + \gamma_{iv} + \theta_v + \delta_{st} + \epsilon_{ivt}$$

in which *UltrasoundExp*BornPost1980* is estimated from the NFHS II dataset in the first stage regression as follows:

$$\begin{aligned} UltrasoundExp * BornPost1980_{ivt} = \alpha + \beta_1 HealthFacilityAccess_{iv} * BornPost1980_{ivt} \\ + \beta_2 HealthFacilityAccess_{iv} + \gamma_{iv} + \psi_s + \epsilon_{ivt} \end{aligned}$$

HealthFacilityAccess is a continuous village level average of a binary variable on health facility use: households report where their most recent child was delivered and are coded as having access to a major health facility if they report doing so in a government hospital, government dispensary, UHC, PHC, non-governmental clinic, or private hospital.[30] I use place of delivery as a proxy for access because childbirth is the most serious medical condition for which the NFHS documents the place of care.

The reduced form equation includes village (θ) and state by year (δ) fixed effects, and the first stage includes state (ψ) fixed effects. Controls in the reduced form include religion, age, wealth index, education, occupation, education and occupation of the respondent's spouse, while the first stage includes controls for the respondent's education, occupation, education and occupation of the respondent's spouse, and socioeconomic status living index (the NFHS-II version of the wealth index in NFHS-III). My sample consists of all respondents born between 1976 and 1984. I am required to decrease the upper range of birth years from that of earlier specifications because respondents in the sample used to estimate *Ultrasound*Post*

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[30] Households are denoted as not having access to a major health facility if they delivered their child in any of the following: a subcentre, a government mobile clinic, a private clinic that is not a hospital, or in someone's home.

can be born no later than 1984 in order to be eligible to participate in the 1999 NFHS II survey.

Results are presented in Table 13. Standard errors are corrected for the two sample 2SLS procedure following Inoue and Solon (2010). Consistent with the main specification, BMI, marriage age, and age at first birth are significantly lower for women in treated villages (those born after 1980 living in villages with greater ultrasound access as instrumented for by access to a major health facility) than their counterparts. Marriage age gap, tolerance for beating, lack of autonomy, and number of children, and distance from ideal family size are significantly higher for women in treated villages than their counterparts, once again suggesting lower bargaining power for women in villages heavily exposed to ultrasound technology. All other coefficients move in the expected direction but are not statistically significant.[31]

6 Conclusion

The above investigation offers evidence that the introduction of ultrasound has had unintended consequences on the intrahousehold bargaining dynamics of children in skewed and endogenously sex selected marriage markets. I present evidence that parents, when choosing the sex composition of their families, are informed by the conditions of the contemporaneous marriage market (which they presumably use as a proxy for the future marriage market of their unborn children). Availability of sex selection technologies such as ultrasound generates skewed sex ratios which are stratified by wealth: in regions where the rich bear relatively more sons, the poor react by bearing relatively more daughters.

I argue that this landscape of skewed and endogenously sex selected populations manifests in poorer intrahousehold bargaining outcomes for females upon reaching marriageable age through the mechanism of poorer assortative matching in the marriage market. I offer evidence that the 'quality' of the average female in regions where ultrasound availability is high is considerably poorer than that of her counterpart in a low ultrasound region, consistent with the predictions of wealth-stratified sex selection. I present further results that female bargaining power within a marriage, as measured by tolerance for abuse and childbearing dynamics, is significantly lower in regions with high ultrasound exposure relative to those in low exposure areas.

These findings fill a significant gap in the literature. Simple models of scarcity are not sufficient to explain the marriage market implications of sex imbalances that arise from

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[31] While access to a major health facility may be correlated with other village-specific time trends, all obvious correlates would predict outcomes moving in the opposite direction of what we see. For example, health facility access may be correlated with increasing wealth, urbanization, or delivery of other public services, all of which should have positive effects on exposed female cohort health and wellbeing.

parental choice, and yet sex selection is, far and away, the most prevalent source of sex imbalance globally. And while sex ratios stratified by wealth have been noted for decades, this study is the first to explicitly test the mechanism of parental internalization of marriage markets as first proposed by Edlund (1999). As India continues to battle the problem of sex imbalance, both at birth and now in marriage markets, designing effective policy will be impossible without recognizing the source of the existing crisis.

There are two important limitations to this investigation. First, the work thus far cannot differentiate altered marriage market composition due to parental choice of locals from altered marriage market composition due to the migration or trafficking of marriageable women across villages. This is a legitimate concern for welfare measures, since the former scenario would suggest a drop in total welfare while the latter may not, depending on the migrant woman's marital conditions at her place of birth. Unfortunately, I am limited by the available dataset in the extent to which I can explore this issue: the NFHS does not ask questions on place of birth nor distance between husbands' and own village. Using differences in native language as a proxy for marrying a migrant, I find no effect of ultrasound exposure on the likelihood of marrying a migrant. Language is far from an ideal proxy, however, and the test offers less than conclusive evidence against the migration story, which should be further explored in future work. More broadly, this paper makes no claim on the total welfare effect of ultrasound technology upon exposed women. While women do appear to exist in 'poorer' marriages in terms of bargaining power, they are also married to higher-status men, potentially raising their consumption of other welfare-increasing items.

Second, it is important to reiterate the generation gap in the various forms of evidence I have presented. I offer compelling evidence that parents of the present (2000-2005) generation are sex selecting based on anticipated marriage market conditions, but I have less compelling evidence of such motives among parents of the 1981-1989 birth cohort. Though the results demonstrate considerable impacts on matching and intrahousehold bargaining power for this birth cohort upon marriage in the direction consistent with the theory, it may be that the estimated effects for this cohort are driven by two alternative mechanisms: (1) a marriage squeeze story, in which older men marry younger women in high ultrasound regions where similar-age women are scarce, leading to a larger education gap and consequently bargaining power gap, or alternatively (2) a credit constraints story, in which the rich have greater access to ultrasound due to wealth, so they sex select more, while the poor remain the same given credit constraints, sex selecting only when they have access. Both channels are plausible. I stress, however, that the evidence on parental internalization of the marriage market suggests that endogenous selection by wealth strata will kick in with greater force during the present generation of just-born children, resulting in an inevitable *exacerbation* of sex segregation by wealth and the intrahousehold dynamics observed in this study once this generation reaches marriageable age.

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Tables

Table 1: Parents internalizing the marriage market

	Fraction of male children born in 2000-2005 (household)				
	(1)	(2)	(3)	(4)	(5)
Fraction of males in marriage market (village)	-0.0256*	0.0496	0.0628		0.0220
	[0.0155]	[0.0500]	[0.0510]		[0.0179]
Fraction of marriage market males * Poor		-0.110**	-0.121**	-0.123	-0.0332*
		[0.0488]	[0.0500]	[0.0784]	[0.0174]
Poor		0.0358	0.0496*	0.0492	0.000916
		[0.0277]	[0.0285]	[0.0440]	[0.0134]
Mean fraction of male children among rich in less skewed markets	0.535	0.535	0.535	0.535	0.535
	[0.468]	[0.468]	[0.468]	[0.468]	[0.468]
Caste FE			X	X	X
Religion FE			X	X	X
State * Village size FE			X		X
Village FE				X	
F-stat: coef(Fr. of marriage market males) = coef(Fr. of marriage market males * Poor)		0.0338	0.0318		0.1272
Observations	31,365	25,013	24,029	24,029	24,298

Notes: Standard errors clustered at village level. Poor is a binary variable which equals one if the household falls in the bottom two wealth quintiles and zero if the household falls in the top two wealth quintiles (those in the middle quintile are excluded from the sample). Columns 1-4 employ a continuous measure of the fraction of males in the marriage market as the independent variable, while column 5 employs a binary version which equals one if the fraction of males in the village marriage market is above the median (0.524) and zero otherwise. The final row, "Mean fraction of male children for rich in less skewed markets," is not an independent variable in the regression but rather an approximation of the omitted category, where less skewed markets are those below the median. The specification in column 1 includes controls for urban, education, spouse's education, religion, occupation, and spouse's occupation (not shown). The remaining specifications in columns 2-5 additionally include interactions of each of these control variables with the fraction of males in the marriage market.*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 2: Parents internalizing the marriage market

	Less skewed marriage market	More skewed marriage market	Average
Panel A	Existing context		
Poor child sex ratio	0.535	0.502	0.519
Rich child sex ratio	0.535	0.557	0.546
Gap			**0.028**
Panel B	Credit constrained context		
Poor child sex ratio	0.535	0.535	0.535
Rich child sex ratio	0.535	0.557	0.546
Gap			**0.011**

Table 3: Parents internalizing the marriage market across wealth

	Fraction of male children born in 2000-2005 (household level)
Marriage market males * Gap * Poor	-0.517**
	[0.250]
Marriage market males * Gap	0.0527
	[0.162]
Gap * Poor	0.256*
	[0.134]
Marriage market males * Poor	-0.145
	[0.104]
Marriage market males	0.193*
	[0.101]
Gap	-0.00808
	[0.0879]
Poor	0.0703
	[0.0576]
Constant	0.396***
	[0.113]
Observations	7,918

Notes: Standard errors in brackets, clustered at the village level. Sex ratios calculated for 2000-2005 births (sex ratio of children born in those years) and marriage market (individuals eligible in those years) only. For marriage market, youngest person observed is 14 in 2000, oldest observed is 34 in 2005. Full set of controls included (and not shown): village level sex ratio of children born between 1991-1995, rural, education of respondent, education of spouse, religion, and interactions of each of these variables with the fraction of males in the marriage market. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 4: Ultrasound exposure and demographic characteristics

	Village level ultrasound exposure for first births
Rural	-0.0859***
	[0.00565]
Wealth index	0.0279***
	[0.00146]
Education	0.0167***
	[0.00119]
Education of spouse	0.00566***
	[0.000939]
Occupation	0.00109**
	[0.000555]
Occupation of spouse	0.00344***
	[0.000603]
Religion	0.000165*
	[9.30e-05]
Constant	0.126***
	[0.00701]
Observations	92,658

Notes: Standard errors in brackets, clustered at village level. State fixed effects included. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Relationship between self reported ultrasound use and parental treatment after birth

	(1) Coefficient on ultrasound	(2) Outcome mean	(3) N
PANEL A: FEMALES			
Breastfeeding duration	-0.459***	13.15	21,895
	[0.171]		
Ever received vaccination	0.00692	0.87	14,528
	[0.00990]		
Hour put to breast	3.006***	20.74	15,409
	[0.948]		
Post natal check received	0.0168	0.09	6,938
	[0.0294]		
Size at birth (quintiles)	0.0350	2.99	21,563
	[0.0215]		
Current child weight (kg)	0.0504	9.98	19,758
	[0.0517]		
Current child height (cm)	-0.0661	81.35	19,683
	[0.214]		
Anemia	-0.0452*	1.05	15,936
	[0.0262]		
PANEL B: MALES			
Breastfeeding duration	-0.300*	13.20	23,752
	[0.158]		
Ever received vaccination	-0.000761	0.88	15,498
	[0.00916]		
Hour put to breast	3.007***	21.12	17,903
	[0.860]		
Post natal check received	0.0252	0.10	7,658
	[0.0293]		
Size at birth (quintiles)	-0.00330	3.04	23,393
	[0.0198]		
Current child weight (kg)	0.0663	10.56	21,495
	[0.0481]		
Current child height (cm)	-0.0605	82.96	21,426
	[0.197]		
Anemia	-0.0386	1.07	17,726
	[0.0239]		

Notes: Standard errors clustered at village level. ”Ultrasound” is whether the mother used ultrasound in her first birth. Controls include mother’s age, child’s age, household wealth index, religion, mother’s education and occupation, and sex interacted with the previous controls. Village fixed effects also included. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Comparing child-related outcomes for children born after 1999 across villages with varying exposure to ultrasound

	(1) Hour put to breast	(2) Breastfeeding duration	(3) Postnatal check	(4) Ever received vaccination	(5) Size at birth	(6) Weight at survey age	(7) Height at survey age	(8) Has anemia
PANEL A: MOTHER FIXED EFFECTS								
Male child * Ultrasound		0.599		-0.00412	0.0422	-0.241	-0.715	-0.0262
		[0.956]		[0.0429]	[0.102]	[0.260]	[1.084]	[0.172]
Male child		-0.172		0.00958	0.0597*	0.552***	1.346***	0.0106
		[0.275]		[0.0122]	[0.0315]	[0.0661]	[0.285]	[0.0498]
Observations		46,040		30,269	45,340	41,588	41,441	33,950
PANEL B: VILLAGE FIXED EFFECTS								
Male child * Ultrasound	2.914*	0.258	-0.0506	-0.0193	-0.0197	-0.127	-0.418	0.0963**
	[1.609]	[0.306]	[0.0481]	[0.0147]	[0.0351]	[0.0820]	[0.324]	[0.0440]
Male child	0.120	0.00364	0.0141**	0.00916*	0.0548***	0.546***	1.363***	-0.00648
	[0.507]	[0.0909]	[0.00592]	[0.00477]	[0.0112]	[0.0227]	[0.0964]	[0.0129]
Observations	33,589	45,992	14,682	30,238	45,293	41,547	41,400	33,915
Mean of outcome	20.91	13.18	0.09	0.878	3.01	10.28	82.198	1.0569
	[32.91]	[7.42]	[0.29]	[0.33]	[0.84]	[3.22]	[14.26]	[0.90]

Notes: Standard errors clustered at mother level for Panel A and at village level for Panel B. "Ultrasound" is the village level average of ultrasound use at first births. Age put to breast and postnatal check are not reported in Panel A because there exist no observations of sons and daughters of the same mother, as the question was only asked for the youngest child in the family. All regressions control for child age in months and fixed effects for child birth order. Regressions in Panel B additionally control for number of antenatal visits (only elicited for youngest child), household religion, mother's education, household wealth index, a dummy for whether the home is urban, and mother's age and age squared. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 7: Marriage market internalization across ultrasound exposure

	Fraction of male children born in 2000-2005 (household level)		
	(1) Full sample	(2) No ultrasound	(3) Positive ultrasound
Marriage market males * Gap * Poor	-0.517**	0.419	-0.590**
	[0.250]	[0.531]	[0.287]
Marriage market males * Gap	0.0527	-0.877*	0.219
	[0.162]	[0.457]	[0.165]
Gap * Poor	0.256*	-0.252	0.305**
	[0.134]	[0.289]	[0.153]
Marriage market males * Poor	-0.145	-0.1000	-0.139
	[0.104]	[0.211]	[0.120]
Marriage market males	0.193*	0.186	0.175
	[0.101]	[0.197]	[0.114]
Gap	-0.00808	0.467*	-0.0899
	[0.0879]	[0.251]	[0.0899]
Poor	0.0703	0.0468	0.0646
	[0.0576]	[0.111]	[0.0670]
Constant	0.396***	0.0451	0.615***
	[0.113]	[0.204]	[0.131]
Observations	7,918	2,392	5,539

Notes: Standard errors in brackets, clustered at the village level. Sex ratios calculated for 2000-2005 births (sex ratio of children born in those years) and marriage market (individuals eligible in those years) only. For marriage market, youngest person observed is 14 in 2000, oldest observed is 34 in 2005. Full set of controls included (and not shown): village level sex ratio of children born between 1991-1995, rural, education of respondent, education of spouse, religion, and interactions of each of these variables with the fraction of males in the marriage market. *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Difference in difference for composition outcomes

	(1) BMI	(2) Weight	(3) Height (cm)	(4) Educ. (years)
Ultrasound village * Born post 1980	-0.880***	-1.577***	0.792**	-0.0876**
	[0.236]	[0.608]	[0.397]	[0.0429]
Mean of outcome pre-1981	20.990	48.799	152.274	1.360
	[3.775]	[9.854]	[5.939]	[1.076]
Observations	32,833	32,883	32,874	34,284

Notes: Standard errors clustered at the village level. Village fixed effects and state by village size by birthyear fixed effects included in all regressions. Outcomes observed in 2005 from NFHS III survey; sample includes only married women born between 1976 and 1988. Additional controls (not shown) include religion, wealth index, occupation, spouse's education and occupation, and age. Columns 1-3 also include education of respondent. *** $p<0.01$, ** $p<0.05$, * $p<0.1$, corrected for multiple hypothesis testing using Anderson (2008) for all outcomes in Table 8 and Table 10.

Table 9: Matching gap in marriage market of exposed females

	Husband's education
Ultrasound * Post * Education of wife	-0.0842**
	[0.0413]
Ultrasound village * Born post 1980	0.110
	[0.0885]
Ultrasound village * Education of wife	0.0355
	[0.0333]
Post * Education of wife	-0.0138
	[0.0132]
Education of wife	0.310***
	[0.0115]
Constant	0.142
	[0.217]
Observations	34,284

Notes: Standard errors clustered at the village level. Village fixed effects and state by village size by birthyear fixed effects included in all regressions. Outcomes observed in 2005 from NFHS III survey; sample includes only married women born between 1976 and 1988. Additional controls (not shown) include religion, wealth index, occupation, spouse's occupation, and age. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 10: Difference in difference in matching and bargaining outcomes

	(1) Marriage age gap	(2) Marriage age	(3) Physical abuse	(4) Beating	(5) No autonomy
Ultrasound village * Born post 1980	1.269***	-1.051***	-0.0361	0.0550*	0.00954
	[0.262]	[0.200]	[0.0352]	[0.0287]	[0.0329]
Mean of outcome pre-1981	5.575	18.242	0.318	0.424	0.440
	[4.221]	[3.788]	[0.499]	[0.494]	[0.496]
Observations	32,279	32,833	25,641	32,833	32,373

	(6) Age at first birth	(7) Interval between marriage and birth	(8) Number of children	(9) Fraction of male children	(10) Distance from ideal number of children
Ultrasound village * Born post 1980	-1.093***	-3.978***	0.860***	0.0558*	0.705***
	[0.205]	[1.466]	[0.0727]	[0.0303]	[0.0740]
Mean of outcome pre-1981	19.774	22.686	2.223	0.532	-0.086
	[3.505]	[20.279]	[1.560]	[0.343]	[1.428]
Observations	29,019	29,019	32,833	29,019	32,330

Notes: Standard errors clustered at the village level. Village fixed effects and state by village size by birthyear fixed effects included in all regressions. Outcomes observed in 2005 from NFHS III survey; sample includes only married women born between 1976 and 1988. Additional controls (not shown) include religion, wealth index, education, occupation, spouse's education and occupation, age, BMI, weight, and height. *** $p<0.01$, ** $p<0.05$, * $p<0.1$, corrected for multiple hypothesis testing using Anderson (2008) for all outcomes in Table 8 and Table 10.

Table 11: Placebo difference in difference in composition outcomes

	(1) BMI	(2) Weight	(3) Height (cm)	(4) Educ. (years)
Ultrasound village * Born post 1970	0.0650	0.172	0.216	0.0745*
	[0.250]	[0.634]	[0.348]	[0.0383]
Mean of outcome pre-1971	22.114	51.404	152.119	1.054
	[4.444]	[11.546]	[5.853]	[1.055]
Observations	37,226	37,305	37,297	38,895

Notes: Standard errors clustered at the village level. Village fixed effects and state by village size by birthyear fixed effects included in all regressions. Outcomes observed in 2005 from NFHS III survey; sample includes only married women born between 1966 and 1978. Controls include religion, wealth index, education, occupation, spouse's education and occupation, and age interacted with the previous controls. Additional controls (not shown) include religion, wealth index, occupation, spouse's education and occupation, and age. *** p<0.01, ** p<0.05, * p<0.1, corrected for multiple hypothesis testing using Anderson (2008) for all outcomes in Table 11 and Table 12.

Table 12: Placebo difference in difference in matching and bargaining outcomes

	(1) Marriage age gap	(2) Marriage age	(3) Physical abuse	(4) Beating	(5) No autonomy
Ultrasound village * Born post 1970	-0.564**	1.189***	-0.0204	-0.0121	0.0272
	[0.256]	[0.230]	[0.0326]	[0.0253]	[0.0291]
Mean of outcome pre-1971	5.634	18.206	0.326	0.440	0.425
	[4.702]	[4.422]	[0.533]	[0.496]	[0.494]
Observations	36,553	37,226	29,759	37,226	36,649

	(6) Age at first birth	(7) Interval between marriage and birth	(8) Number of children	(9) Fraction of male children	(10) Distance from ideal number of children
Ultrasound village * Born post 1970	1.668***	4.262***	0.137*	-0.00763	0.148**
	[0.226]	[1.379]	[0.0729]	[0.0198]	[0.0721]
Mean of outcome pre-1971	20.193	25.891	3.420	0.537	0.925
	[4.270]	[25.464]	[1.990]	[0.290]	[1.741]
Observations	36,034	36,034	37,226	36,034	36,386

Notes: Standard errors clustered at the village level. Village fixed effects and state by village size by birthyear fixed effects included in all regressions. Outcomes observed in 2005 from NFHS III survey; sample includes only married women born between 1966 and 1978. Additional controls (not shown) include religion, wealth index, education, occupation, spouse's education and occupation, age, BMI, weight, and height. *** p<0.01, ** p<0.05, * p<0.1, corrected for multiple hypothesis testing using Anderson (2008) for all outcomes in Table 11 and Table 12.

Table 13: Two sample two stage least squares with access to major health facility: composition outcomes

	(1) BMI	(2) Weight	(3) Height (cm)	(4) Educ. (years)
Access to health facility * Born post 1980	-16.06***	-83.46	3.152	-1.19e-07
	[5.133]	[59.03]	[1.991]	[1.77e-07]
Mean of outcome pre-1981	24.373	87.538	152.25	1.229
	[16.111]	[187.510]	[5.859]	[1.055]
Observations	44,742	44,742	43,022	44,742

Notes: Standard errors clustered at the village level. Village and state by birthyear fixed effects included in all regressions. Outcomes observed in 2005 from NFHS III survey; sample includes only married women born between 1976 and 1984. Access to health facility is an instrument for village level ultrasound use from the NFHS II survey collected in 1999. Additional controls (not shown) include religion, wealth index, occupation, spouse's education and occupation, and age. *** *** $p<0.01$, ** $p<0.05$, * $p<0.1$, corrected for multiple hypothesis testing using Anderson (2008) for all outcomes in Table 11 and Table 12.

Table 14: Two sample two stage least squares with access to major health facility: bargaining outcomes

	(1) Marriage age gap	(2) Marriage age	(3) Physical abuse	(4) Beating	(5) No autonomy
Access to health facility * Born post 1980	6.368***	-8.559***	0.156	0.259*	0.360**
	[1.438]	[0.939]	[0.183]	[0.156]	[0.171]
Mean of outcome pre-1981	5.561	18.115	0.325	0.434	0.421
	[4.245]	[3.810]	[0.517]	[0.496]	[0.494]
Observations	42,445	43,022	35,304	43,022	43,022

	(6) Age at first birth	(7) Interval between marriage and birth	(8) Number of children	(9) Fraction of male children	(10) Distance from ideal number of children
Access to health facility * Born post 1980	-7.810***	8.622	6.020***	0.130	4.407***
	[0.978]	[6.919]	[0.406]	[0.156]	[0.413]
Mean of outcome pre-1981	19.910	23.240	2.710	0.534	0.333
	[3.705]	[21.252]	[1.500]	[0.333]	[1.353]
Observations	40,111	40,111	43,022	40,111	42,341

Notes: Standard errors clustered at the village level. Village and state by birthyear fixed effects included in all regressions. Outcomes observed in 2005 from NFHS III survey; sample includes only married women born between 1976 and 1984. Access to health facility is an instrument for village level ultrasound use from the NFHS II survey collected in 1999. Additional controls (not shown) include religion, wealth index, education, occupation, spouse's education and occupation, age, BMI, weight, and height. *** *** p<0.01, ** p<0.05, * p<0.1, corrected for multiple hypothesis testing using Anderson (2008) for all outcomes in Table 11 and Table 12.

Figures

Figure 1: Composition Outcomes

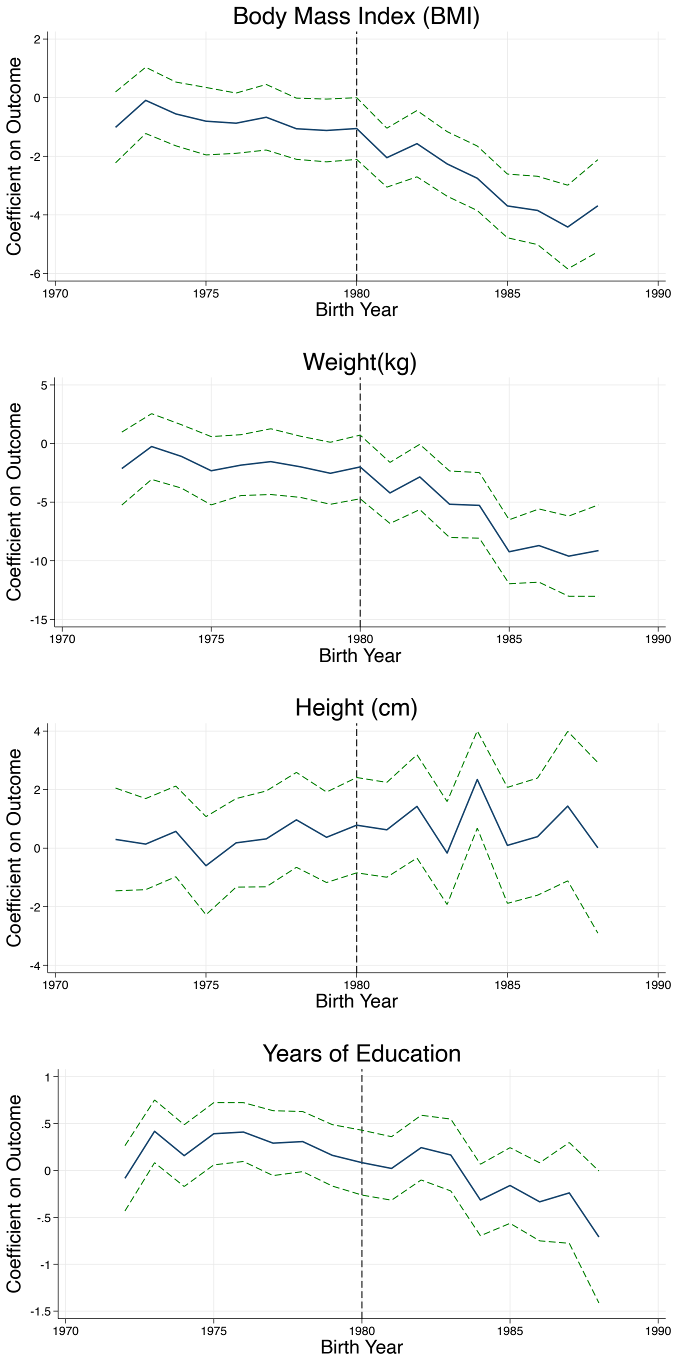


Figure 2: Matching Outcomes

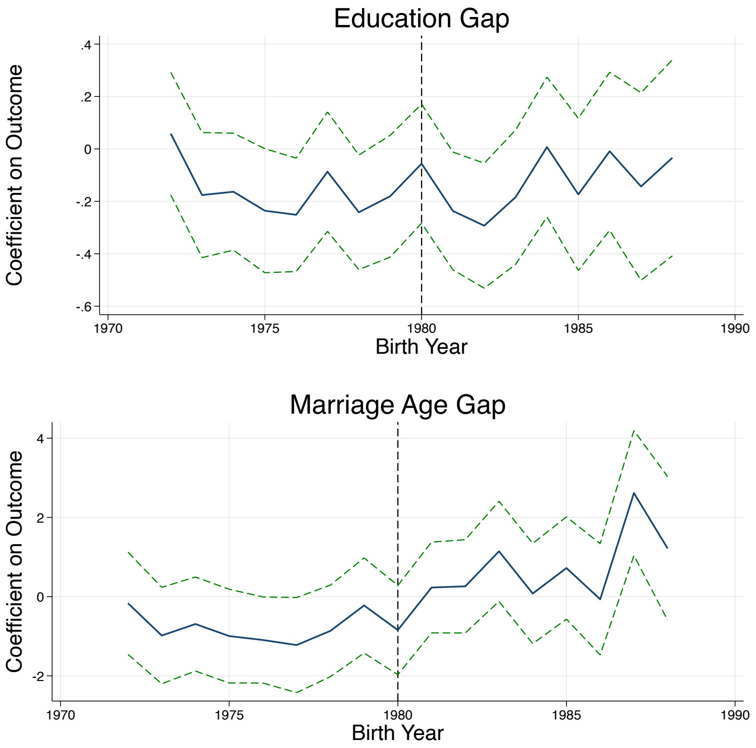
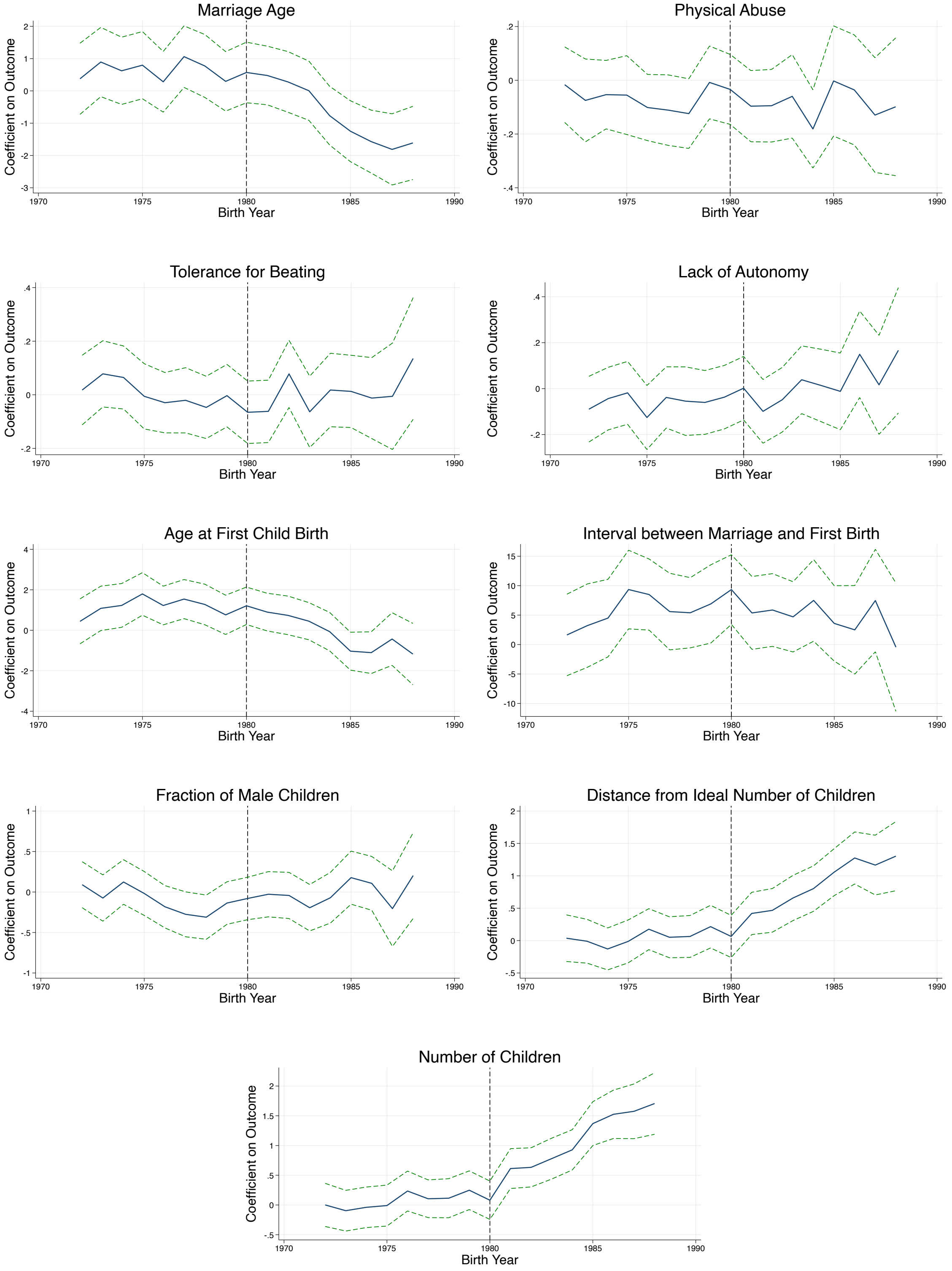


Figure 3: Bargaining Outcomes



A Appendix

A.1 Tables

Table A1: Population differences across wealth

	(1) Fraction of boys in rich strata	(2) Fraction of boys in poor strata	(3) Gap
Positive ultrasound * Post 1980	0.0333	-0.0487*	0.0800
	[0.0311]	[0.0254]	[0.0710]
Post 1980	-0.0416	0.0239	-0.0592
	[0.0297]	[0.0162]	[0.0605]
Mean of outcome in pre-1981 no ultrasound	0.541	0.51	0.057
	[0.400]	[0.351]	[0.528]
Village FE	X	X	X
Observations	54,676	38,256	25,863

Notes: Standard errors clustered at the village level. "RichFractionBoys" is defined as the leave-self-out fraction of males who are rich out of all rich children of marriageable age by 2005 in the village (i.e. the sex composition of rich children that each child i is facing), separately calculated for those children born prior to the availability of ultrasound technology (1976-1980) and those born after (1981-1989), "PoorFractionBoys" is the analogous sex composition of the poor, and "Gap" is the difference between the two. "Post 1980" is a dummy variable equal to one if child was born between 1981-1988 and zero if child was born between 1976-1980. Fractions composed of children born 1976-1980 for those in the pre-period and children born 1981-1988 for those in the post period. "Rich" are those from families in the top two quintiles of the wealth distribution; "Poor" are those in the bottom two quintiles of the wealth distribution. "Gap" is the difference between the fraction of boys in the wealthy strata and the poor strata, by pre/post time period. Ultrasound exposure is a dummy variable equalling 1 if a village reports positive use in first births 2000-2005 and zero otherwise.. Regressions include village fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

A.2 Figures

Figure A1: Payoff Matrix for Parental Sex Selection

Poor/Rich	US_m	US_f	$noSS$
US_m	$U(m_P) - C$ $U(m_R) - C$	$U(f_{PR}) - C$ $U(m_{RP}) - C$	$0.5[U(m_P) + U(f_{PR})]$ $0.5[U(m_{RP}) + U(f_R)] - C$
US_f	$U(m_P) - C$ $U(f_R) - C$	$U(f_P) - C$ $U(f_R) - C$	$0.5[U(m_{PP}) + U(f_{PP})]$ $U(f_R) - C$
$noSS$	$U(m_P) - C$ $0.5[U(m_{RR}) + U(f_{RR})]$	$U(f_P) - C$ $0.5[U(m_{RR}) + U(f_{RR})]$	$0.5[U(m_{PP}) + U(f_{PP})]$ $0.5[U(m_{RR}) + U(f_{RR})]$

Figure A2: Ultrasound use by wealth

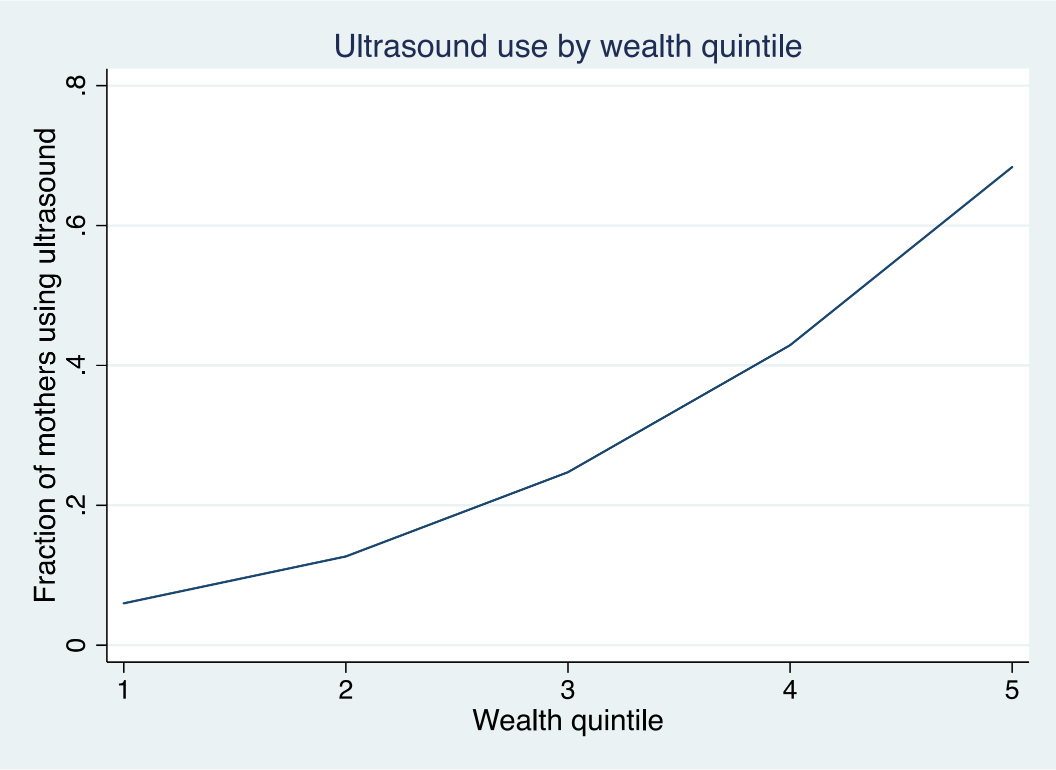


Figure A3: Birth order and son preference

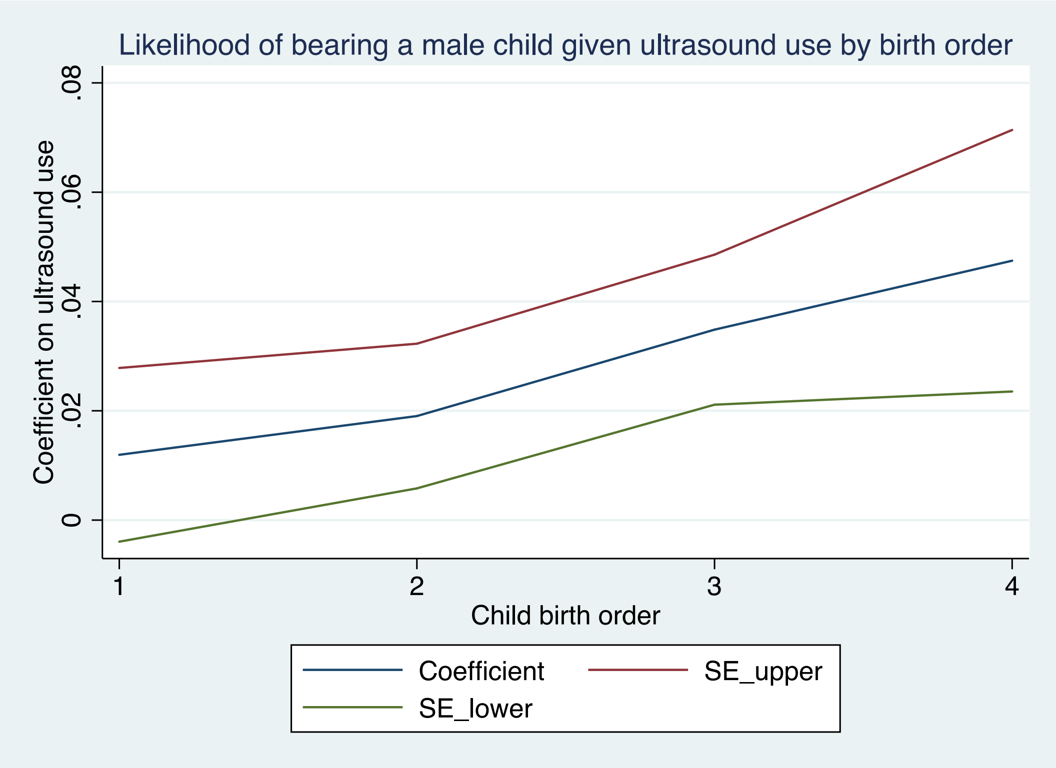


Figure A4: Distribution of ultrasound