Prenatal Sex Detection Technology and Mothers' Labour Supply in India †

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Abstract

This paper investigates the impact of prenatal sex detection technology (PSDT) on mothers' labour supply in India. Our empirical strategy relies on a triple-differences approach. We combine aggregate supply-driven changes in ultrasound availability over time with plausibly exogenous family-level variation in the incentive to sex-select due to first-born gender and son preference at the local level. We find that PSDT had a significant negative impact on the labour supply of wealthy and educated mothers. For them, the increased availability of ultrasound scanners induced a substitution of girls with boys, with no effect on fertility. A dynamic model of fertility and labour supply decisions shows that the decline in mothers' labour supply largely reflects an income effect due to the lesser need to pay for daughters' dowries.

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1. Introduction

Our paper contributes to the literature that analyses the root causes of the decline in female labour force participation in India. Even though the decline is documented mostly for the last two decades and is partly driven by urbanization, in the paper we focus on causes that relate to fertility decisions that started changing in the late 1990s.

We follow recent literature in relating fertility decisions to the increased availability of ultrasound scans for pregnant women (also known as Prenatal Sex Detection Technology, or PSDT). This, together with widespread (but not universal) son preference led to a surge in selective abortions. We use micro data to show that this surge did not lead to a decreased fertility overall - rather a "rebalancing" of the gender of the second born children to males. Using a triple-difference identification strategy we then show that this in turn led to a reduction in labour supply mostly by urban, relatively well-off women.

Sex ratios at birth have rapidly become unbalanced over time, from 964 girls born for every 1000 boys in the 1971 Census to 927 girls in 2001. This marked decrease has been largely attributed to the advent of PSDT, which made it easier for women to identify the sex of their children before their birth, giving them an option to attain the desired family size and sex composition without having to undergo repeated pregnancies.

Ultrasound scanners were first introduced in the 1980s, with the onset of a period of economic liberalization, and became accessible to the general population in the mid-1980s. In the mid-1990s, large-scale domestic production of ultrasound scanners was initiated. The lower cost and the non-invasive nature of ultrasound scans led to their widespread use for foetal sex determination, resulting in a staggering rise in sex-selective abortion, equivalent to 6 per cent of potential female births during 1995-2005 (Bhalotra and Cochrane, 2010).

A large body of literature has shown that son preference in India has led to poor socioeconomic outcomes for daughters, including female infanticide, excess mortality, and health neglect (Sen, 1992). The resulting biased sex ratio also has implications for marriage market imbalance, violence against women, prostitution, and sexually transmitted diseases, among others (Amaral and Bhalotra, 2017; Ebenstein and Sharygin, 2009; Edlund, 1999; Edlund et al., 2007). Anukriti et al. (2022) and Hu and Schlosser (2015) show that the introduction of PSDT led to a reduction in girls' neonatal and post-neonatal mortality rates, and improved parental investment in vaccination and breastfeeding.

Little is known instead about the effects of PSDT on mothers' outcomes. We investigate the impact of this technology on mothers' labour supply and exploring the underlying channels linking

PSDT to mothers' labour supply. There are several reasons why PSDT might impact mothers' labour supply decisions. First, prior to PSDT, to achieve the desired number of sons families had to trade off their desire to have a son with the risk of getting one additional daughter. Given that dowry payments from the bride to the groom's family are still prevalent in India, the birth of a daughter generates a substantial negative income shock on families, who need to save in advance (Anukriti et al., 2022). By reducing families' expected number of daughters, PSDT means lower expected dowry payments in the future, decreasing the necessity for mothers to work. Second, there is evidence that Indian mothers tend to invest more time and resources in sons than daughters, thereby raising the disutility cost of work in the presence of sons and reducing mothers' labour supply (for example, Jayachandran and Kuziemko 2011, provide evidence of longer breastfeeding for male than female babies). The higher male-to-female birth rate induced by PSDT could have thus led mothers to reduce labour supply. Third, by giving women better control over their fertility, PSDT could have altered not only the gender composition of children, but also their total number. If PSDT reduced total fertility, mothers' labour supply could be positively impacted by its introduction, especially if mothers' ability to work was previously limited by repeated pregnancies and the need to care for their children. However, a lower fertility implies fewer mouths to feed, with negative effects on necessity-induced labour supply. Overall, the sign of the effect is a-priori unclear and crucially depends on the effect of PSDT on the male-to-female birth rate and on total fertility.

We estimate the effect of PSDT on mothers' labour supply using survey data from two rounds of the National Family Health Survey, conducted in 1992/93 and 2005/06. The data contain information on the complete fertility history of women, their desired fertility and sex composition of children, their employment status, and various other socioeconomic variables.

We identify the effect of PSDT-induced sex selection on mothers' labour supply using a triple-differences approach. We compare the labour supply of mothers of firstborn sons vs. daughters, before vs. after the introduction of PSDT, in local areas with high vs. low son preference. We use 1995 as a break point in the supply of ultrasound scanners, following the acceleration of economic reforms and domestic production of scanners. Moreover, the sex of the firstborn child provides quasi-random variation in the incentive to conduct sex selection at the family level. As shown by previous research, in fact, the sex of the firstborn child in India is as good as random, but parents with firstborn daughters are more likely to sex-select at later births relative to parents with firstborn sons (see for ex. Almond and Edlund, 2008; Bhalotra and Cochrane, 2010; Edlund, 1999; Kugler and Kumar, 2017).

Anukriti et al. (2022) and Bhalotra and Cochrane (2010), combine these two sources of variation in a difference-in-difference approach to identify the effect of PSDT on fertility and daughters' outcomes. We are however worried that the gender of firstborn-specific shocks concurrent with PSDT introduction and impacting maternal labour supply may bias the difference-in-differences design. For example, the observed simultaneous improvement in women's education (see e.g., MOSPI, 2017) might have led mothers to invest more in daughters. This trend may have in turn negatively impacted the labour supply of mothers with firstborn daughters even in the absence of the introduction of PSDT. To overcome this issue, we strengthen our research design by following Hu and Schloesser (2016) and leveraging also the variation across Indian local areas with high and low son preference, measured by the male-to-female ratio of children aged 0-6 by state and rural/urban areas, as observed in the 1981 Indian Census – before the introduction of ultrasound scans. This measure reflects son preference in so far as unwanted daughters are more likely to die in their early childhood due to lack of care or insufficient nutrition. The identifying assumption in our triple-differences design is that differences-in-difference (DiD) estimates from low son-preference states capture the natural trends in maternal labour supply by firstborn gender that would have been observed in high son-preference states without PSDT.

We can summarise our results as follows. First, the introduction of PSDT led to a significant and large reduction in mothers' labour supply of 2.3 percentage points, or 8.5 percent of the sample mean. Second, we consistently find that the wider availability of sex selection technology induced a 1 to 1 substitution of daughters with sons, with no impact on the total number of children. Third, we find that the effects on both fertility and labour supply are entirely driven by wealthy and educated women – a result that likely stems from their higher possibilities to access to PSDT and abortion facilities.

To better understand the economic mechanisms behind our uncovered effects, in the final part of the paper we develop a three-period life cycle model of fertility and labour supply decisions of mothers. The model incorporates two important features of the Indian dowry system, namely that mothers start saving for dowries when a daughter is born (Anukriti et al., 2022), and that dowry payments are increasing in wealth (Borker et al., 2022). We further assume that, as observed in the data, PSDT use is substantially more frequent among wealthier families. The calibrated model can replicate the estimated effects of PSDT on fertility and labour supply by wealth, and it further shows that dowries can largely explain these effects, as well as their gradient by wealth. Finally, the model also shows that differences in the disutility cost of work by gender of children would need to be implausibly large in order to generate the observed results without introducing dowries in the model.

The paper is organized as follows. In Section 2 we review Indian social norms concerning son preference and the practice of selective abortions. Section 3 describes the micro data we use, while Section 4 presents and justifies our triple difference identification strategy. Section 5 presents estimation results, both for the full sample and for sample splits based on education and wealth. Section 6 illustrates a stylized theoretical model that allows us to identify the mechanisms behind the estimated labour supply effects. Section 9 concludes.

2. Background and Institutional Framework

India is characterized by a high prevalence of son preference. Prior research has identified some important social, religious and economic reasons that may potentially contribute to the presence of son preference, such as the financial and labour contributions of sons to the family, their perpetuation of the family name, dowry practice, the entitlement of sons to perform certain religious ceremonies, and sons being the source of old-age support (Arnold et al., 1998, 2002; Mutharayappa et al., 1997; Vlassoff, 1990).[1]

Indian families express a strong preference for having at least one son, and often two, among their children (Mutharayappa et al., 1997). In order to achieve their ideal number of sons, parents often practice son-preferring Differential Stopping Behaviour and continue having children until the ideal number of sons is achieved.

The biologically normal population sex ratio (sons to daughters) at birth ranges from 1.03 to 1.07. Sex ratios at birth above 1.07 suggest that pre-birth interventions are reducing the likelihood of a female birth. Since 1981 India has experienced a sharp rise in the male-to-female ratio (MFR) at birth. In 1971 there were 964 girls for every 1000 boys at birth, which is in the "normal" range. The number of girls diminished at an increasing rate over the next three decades, reaching 927 in 2001 (Bhalotra and Cochrane, 2010). This fall in the number of girls for every 1000 boys at birth since 1981 has been attributed to the legalization of abortion along with the increased access to PSDT, which enabled women to undergo the abortion of unwanted female children. According to Bhalotra and Cochrane (2010), in the post-ultrasound regime (1995-2005) half a million girls per annum were selectively aborted in India.

[1] Past studies have also documented adverse consequences of son preference, such as excess female child mortality, neglect of female health and nutrition, especially-but not exclusively-during childhood, including access to preventive care, feeding, and immunization (Arnold et al., 1998, 2002; Clark, 2000; Gupta, 2020; Mutharayappa et al., 1997; Sabarwal, 2008; Sen, 1992)

Abortion was legalized in India in 1971, with the passage of the Medical Termination of Pregnancy 1971 Act, effective in most states in 1972 (Arnold et al., 2002). The act was passed to regulate and ensure access to safe abortion for women and reduce maternal death due to unsafe abortions. Sex determination of the foetus in India first became possible with the advent of amniocentesis in the 1970s. However, due to high direct costs and the invasiveness of amniocentesis, its widespread usage was limited (Anukriti et al., 2022). According to Grover and Vijayvergiya (2006), before the early 1980s, sex determination was only done to study sex-linked disorders and for DNA testing in health research institutes.

Foetal sex selection only really became feasible after 1980, with the onset of liberalizations and the arrival of ultrasound scanners (Bhalotra and Cochrane, 2010). Demand for ultrasound scans proliferated as a result of the technology being non-invasive and of its affordability – at about \$10-\$20 for a scan (Arnold et al., 2002). By the mid-1990s, import tariffs for medical devices were largely reduced, and large-scale local production of ultrasound scanners was initiated[2]. According to government data, the number of ultrasound machines manufactured in India increased 33 times between 1988 and 2003 with especially marked increases after 1994 (Bhalotra and Cochrane, 2010; George, 2006; Grover and Vijayvergiya, 2006).

Anukriti et al. (2022) show that the evolution of ultrasound use closely tracks the one of ultrasound machines availability, and so does the trend in the officially reported number of abortions, which displays a steep acceleration after 1995. Using data from NFHS rounds 2 and 3 and data on the officially reported number of abortions, they show a positive correlation between the fraction of births with ultrasound use and the number of abortions by state and year. Given the rising male-to-female ratio, sex selection has become the dominant concern amongst women and human rights organizations. In 1994, the Prenatal Sex Diagnostic Techniques (Regulation and Prevention of Misuse) (PNDT) Act was passed. The Act became operational in 1996 and made it illegal to use prenatal sex-diagnostic techniques to reveal the sex of a foetus. However, the act was difficult to enforce, hardly any cases of violation were reported from the states and no one was punished (Visaria, 2005). The 2001 Census revealed continuing deterioration in the sex ratio. Following this public interest, a litigation was filed in the Supreme Court by some non-governmental organizations. This led to the amendment and strengthening of the PNDT Act in 2002, incorporating a ban on advertising

[2] The number of imported ultrasound scanners, as reported by Mahal et al.(2006), were 742 during 1991-94, 1135 during 1994-97, 1737 during 1997-2000, and 4733 during 2000-03. And the number of domestically produced ultrasound machines were 1314 during 1988–91, 5651 during 1992–95, 11290 during 1996–99, and 19581 during 2000–03 (George, 2006).

prenatal sex determination and increased penalties for violations. There has been mixed evidence on whether these regulations made any difference (Nandi and Deolalikar, 2013; Visaria, 2005).

The literature has also documented heterogeneity in the practice of sex selection across states, social groups and economic groups (see for ex. Almond and Edlund, 2008; Anukriti et al., 2022; Arnold et al., 2002; Bhalotra and Cochrane, 2010; Hu and Schlosser, 2015; Mutharayappa et al., 1997; Sabarwal, 2008). Son preference in terms of the stated ideal male-to-female ratio is observed throughout India, but it is particularly high for northern states as well as Uttar Pradesh, Bihar and Gujarat.

Importantly, wealthier households in India are more likely to use sex selection techniques, as measured both by the use of ultrasound as well as the incidence of skewed sex ratios (Jayachandran and Pande, 2017). Deficits of girls among higher birth order children with no elder brother have been found to be greater among educated women and economically well-off families (Akbulut-Yuksel and Rosenblum, 2023). According to the Pew Research Center (2022), a woman's wealth and education are robust predictors of ultrasound use: Indian women from the wealthiest households are 35 points more likely than those from the poorest households to have an ultrasound during pregnancy (92% vs. 57%). Ultrasound use is much more common among women with 12 or more years of formal schooling than among women who have no formal education (89% vs. 60%).

Economic reasons may contribute to explain this gap. The cost of an ultrasound scan varied by region, type of facility, method and gestation period ranging from about US$10 to US$20 (Arnold et al., 2002). In a country where many live under the $1.25 a day poverty line, these may be significant costs, especially for poor families. Similarly, the cost of an abortion varied by region, type of facility, method and gestation period, ranging from about US$10 to US$20 in the first trimester and US$40 to US$60 in the second trimester (Duggal, 2005; Bhalotra & Cochrane, 2010; Sundar, 2003).[3] In addition, while access to abortion services was not difficult even in the remotest areas of the country (Duggal, 2005), most abortions were practised in unofficial and non-regulated facilities. Wealthier and more educated women may thus have been more likely to adopt the technology because of less binding budget constraints, a higher ability to assess the risks of the new procedures (Bhalotra and Cochrane, 2010), and an easier access to safe abortion facilities.

[3] In India, data on charges for abortion are not available except in small studies of providers and household-based studies researching health care utilization patters (Duggal, 2005).

3. Data and Descriptive Statistics

We use nationally representative microdata from the National Family Health Survey (NFHS). We use data from NFHS rounds 1 and 3, respectively conducted in 1992-93 and 2005-06. Each NFHS round targeted 99% of India's population residing in its 26 states and surveyed approximately 89-thousand eligible women aged 15-49 years. The survey includes detailed information on women's complete birth history, including the gender and year of birth, their desired fertility and sex composition of children, their employment status, and the demographic and socioeconomic background of their household.

Our analysis compares trends in maternal labour supply before and after the introduction of PSDT. Using non-parametric plots and flexible parametric specifications, Bhalotra and Cochrane (2010) identify 1995 as an important break point in ultrasound availability based on the evidence of sharp increases in the supply of ultrasound scanners following the acceleration of economic reform in the early and mid-90s and the initiation of domestic production (Anukriti et al., 2022). We consistently use 1995 as the breakpoint in the supply of ultrasound to estimate if the increased availability of PSDT affected mothers' labour supply decision.[4]

For the pre-PSDT period, we select the sample of mothers observed in NFHS round 1 and who had their first birth between 1985-93. We observe their labour supply in the survey years 1992-93. For the post-PSDT period, we analogously select the sample of mothers observed in NFHS round 3 who had their first birth between 1998-2006 and observe their labour supply in the survey years 2005-06. Once we eliminate observations with missing values for the variables used in the analysis, we are left with a sample of 50,611 observations.

We report descriptive statistics for all the variables used in the analysis in Table 1. The data are well balanced over time, with 49.3% of observations belonging to the pre-1995 sample and 50.7% to the post-1995 one. Close to 49.1% have firstborn daughters – implying a male-to-female ratio of 103.7 among firstborns, within the biologically normal range. Moreover, around 26.6% of mothers in the sample are working at the time of the NFHS interview.

Our analysis on fertility substantially departs from Anukriti et al., 2022, in the definition of fertility. They select a sample of mothers who were either always exposed or never exposed to ultrasound availability for the year-span of their births. They retain women who had *all* their births recorded up to the NFHS interview date strictly within one of the three time periods – pre-ultrasound

[4] Bhalotra and Cochrane (2010) also identify 1985 as a first break-point in the trend of the average sex ratio at birth. As we lack data on labour supply by firstborn gender prior to 1985, we cannot use this trend break for identification.

(1973-84), early diffusion (1985-94), or late diffusion (1995-2005) – and exclude those mothers whose fertility spans more than one time period. For instance, their analysis would exclude a woman who had her births in the years 1992 and 1996 – as the last birth falls within a different PSDT availability regime than the first one. However, the introduction of PSDT may have changed the fertility intentions of mothers who had not yet reached their desired sibling composition but would not have wanted to undergo an uncontrolled pregnancy. As a result, fertility termination likely depends on PSDT introduction, inducing endogenous sample selection. We sidestep this issue by limiting the observation of fertility to the period between the first birth and 1993 – when we observe labour supply in NFHS round 1 – for mothers who gave birth in the pre-PSDT period, and between the first birth and 2006 – when we again observe labour supply in NFHS round 3 – for mothers in the post-PSDT one, without imposing constraints that depend on potentially endogenous fertility stopping decisions.[5] In the data, we find that mothers in our sample had on average 1.85 births by the time we stop observing their fertility.

We also find that the average age of mothers in the sample is 24 years and the age at first marriage and first birth are 18 and 20 years, respectively. Most mothers (about 71%) in the sample reside in rural areas. Our analysis also uses information on a wealth index of the household where the woman lives that is calculated using data on easy-to-be-observed ownership of assets – such as televisions and bicycles, materials used for housing construction, and types of water access and sanitation facilities – and divided into quintiles. Furthermore, about 46% of mothers have no education and 26% of fathers have no education. Finally, about 82% of the women in the sample are Hindus, and 75% belong to castes other than Scheduled Castes (SC) and Scheduled Tribes (ST), the most disadvantaged groups in India.

Our design also relies on a measure of proclivity to commit sex selection at the local level. To this aim, we use data from the 1981 Indian Census and construct the male-to-female ratio (MFR) of children aged 0 to 6 years in each Indian state, separately for residents in urban and rural areas. This measure shall thus capture the prevalence of son preference before the introduction of ultrasound scanners. We use the MFR for children aged 0 to 6 years instead of the MFR at birth because sex-selective abortion was hardly feasible prior to the availability of PSDT, and most families exercised son preference through discrimination against girls in infancy and during childhood. Hence, the MFR of children between 0 to 6 years shall reveal both neonatal and post-neonatal efforts to carry out sex selection. As a robustness check, we also use an alternative measure of local preference for sons: the

[5] In a robustness test we will show that results are robust when we use smaller samples from NFHS rounds 1 and 2 – carried out in 1992/93 and 1998/99, respectively – and condition on firstborns born between 1991-93 and 1997-99 or between 1990-93 and 1996-99, respectively.

growth in the MFR of children aged 0 to 6 years between the 1981 and 1991 Indian censuses at the state level. This serves as an indicator of the spread of PSDT in the first wave of liberalization. We standardize both the variables of son preference so that they have zero mean and unit standard deviation.

4. Empirical strategy

4.1 Identification

The ideal experiment to estimate the causal effect of access to PSDT on mothers' labour supply would be based on random assignment of access to PSDT across individual (or groups of) women. To the best of our knowledge, however, such an experiment has never been carried out in India or elsewhere. Therefore, our empirical strategy is based on variation in the availability of PSDT and on the proclivity to use the technology and carry out sex selection across groups.

We use a triple-differences approach and combine longitudinal variation in the supply of ultrasound technology in India with cross-sectional variability in incentives and preferences to commit sex selection at the family level – captured by the gender of the firstborn child – and at the local level – as proxied by the 1981 MFR for children aged 0 to 6 years.

Table 1 Descriptive statistics

	Mean	Std. Dev.
Post-1995	0.507	0.003
Firstborn girl	0.491	0.003
Works at the NFHS interview	0.266	0.002
Number of births	1.849	0.005
Age	23.726	0.022
Age at first marriage	17.516	0.018
Age at first birth	20.181	0.019
Marital status (Married)	0.980	0.001
Urban	0.291	0.002
Wealth index		
Bottom quintile	0.180	0.002
Second quintile	0.195	0.002
Third quintile	0.202	0.002
Fourth quintile	0.212	0.002
Top quintile	0.210	0.002
Own education		
No education	0.457	0.003
Lower Primary (0-4)	0.066	0.001
Upper Primary (5-7)	0.151	0.002
Primary Completed (8-9)	0.121	0.002
Secondary(10-11)	0.093	0.002
Senior secondary(12 and above)	0.111	0.002
Husband's education		

No education	0.258	0.002
Lower Primary (0-4)	0.071	0.001
Upper Primary (5-7)	0.157	0.002
Primary Completed (8-9)	0.157	0.002
Secondary(10-11)	0.158	0.002
Senior secondary(12 and above)	0.200	0.002
Religion		
Hindu	0.824	0.002
Muslim	0.118	0.002
Christian	0.023	0.001
Other religion	0.036	0.001
Caste		
SC	0.160	0.002
ST	0.086	0.002
Other castes	0.754	0.002
Local MFR for 0 to 6 years in 1981	1.043	0.000
Growth in MFR (1981-91)	0.061	0.000

Note: The number of observations is 50,611. Data are weighted using population-level weights.

We illustrate our triple-differences strategy as follows. Since PSDT was introduced throughout India at the same time, the comparison of maternal labour supply before and after the 1995 break in its introduction would not be informative about a causal effect because of confounding macroeconomic shocks. As a result, causal identification requires combining this trend break with cross-sectional variation across individuals in the likelihood of engaging in sex selection to craft a DiD design.

Following Bhalotra and Cochrane (2010), and Anukriti et al. (2022), a possibility is to exploit between-mother variation in the gender of the firstborn. To motivate this approach, in Table 2 we provide evidence that mothers of firstborn girls are more likely to engage in sex selection than mothers with firstborn boys after the introduction of PSDT. The table reports the difference in the likelihood of having a boy at the second birth between mothers of firstborn girls vis-à-vis boys, before and after PSDT introduction. The minimal sample selection criteria required for this analysis thus differ from the ones required for our labour supply estimates. While in this case we do not need to limit the sample to those mothers for whom we observe labour supply at a given point in time, we instead need to condition on mothers with at least two births. However, we do not expect the probability of second birth to differ before and after PSDT as the average fertility rate in India throughout the study period between 1985-2005 was more than 3 births per woman. In Table 2, we report results obtained when we carry out this analysis in two samples: *i)* the 29,211 second-born children of the mothers observed in our baseline sample (Panel A – Baseline Sample) – described in Section 3 and on whom we carry out our labour supply analysis; *ii)* a larger auxiliary sample that pools the first three rounds of the NFHS data and includes all second-borns who were born between 1985-94 for the pre-PSDT period and between 1995-2005 for the post-PSDT – irrespective of the birth year of firstborns (Panel B – Auxiliary Sample). This strategy leads us to include information for a total of 100,188 second-borns.

Column 1 of Table 2 is for the pre-PSDT period (1985-94), and column 2 is for the post-PSDT one (1995-2005).[6] As seen in column 1, the probability of a male second birth during the pre-PSDT period did not vary significantly depending on the sex of the firstborn. In contrast, column 2 shows that during the post-PSDT period, this probability was significantly higher for households with firstborn girls. The results hold in both the baseline and auxiliary samples. In column 3, we pool the two samples and use a DiD approach to estimate the change in the probability of having a second-born boy after a firstborn girl in the post-PSDT period compared to the pre-PSDT period. Results are quantitatively the same.

Table 2: The differential probability of having a boy at the second birth by sex of the firstborn child

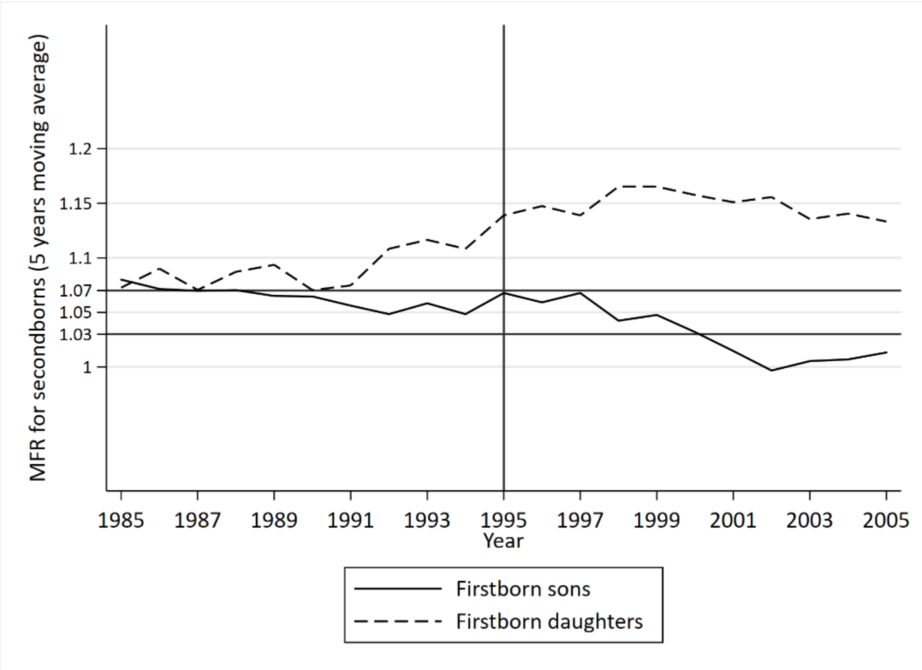
Dependent variable: male child at second birth	(1) Pre-PSDT	(2) Post-PSDT	(3) Pooled
Panel A- Baseline Sample			
Firstborn girl	0.0002	0.034***	0.0014
	(0.006)	(0.009)	(0.006)
Post			0.538***
			(0.027)
Firstborn girl*Post			0.032***
			(0.006)
Controls	Yes	Yes	Yes
Observations	14,867	14,344	29,211
Panel B- Auxiliary Sample			
Firstborn girl	0.008	0.027***	0.008
	(0.006)	(0.008)	(0.006)
Post			0.001
			(0.010)
Firstborn girl*Post			0.0191**
			(0.007)
Controls	Yes	Yes	Yes
Observations	59,572	40,616	100,188

*Note: OLS regression. Additional controls: child's birth year, mother's age, mother's education, mother's marital status, mother's age at first birth and first marriage, indicators for mother's religion and caste, father's education, wealth, rural/urban area and state fixed effects. Baseline and auxiliary samples are defined in the text. Observations are weighted using national-level weights and standard errors are clustered at the state level (in parentheses). *: p<0.1, **: p<0.05, ***: p<0.01.*

[6] Results are comparable both qualitatively and quantitatively when we restrict our sample to children born in 1991/94 and 1995/99.

To further corroborate these findings, we also plot a 5-year moving average of the male-to-female ratio for second-born between 1985-2005 by the gender of firstborns in Figure 1 below.[7] To get reliable year-on-year MFR data, we pool retrospective birth histories from all four survey rounds of the NFHS data conducted in 1992-93, 1998-99, 2005-06, and 2015-16, respectively. A common concern with data from retrospective histories is that they may be marked by inaccuracy in recall. To limit this recall problem, following the literature we left truncate the fertility data and retain index births that occur up to 15 years before each survey date (Anukriti et al., 2022; Bhalotra and Cochrane, 2010).[8] Figure 1 reports an increase in the difference in MFR for second-borns between mothers of firstborn girls and firstborn boys after PSDT became widely available, in the mid-1990s.

Figure 1: Male-to-Female ratio at second birth by gender of the firstborn



Note: The figure plots the 5-year moving average of male to female ratio for secondborns in different years by gender of firstborns. The two horizontal reference lines denote the normal sex ratio (from 1.03 to 1.07). The vertical line denotes the structural break in the availability of PSDT in 1995. We use NFHS rounds 1, 2, 3, and 4 conducted in 1992-93, 1998-99, 2005-06, and 2015-16, respectively. To avoid recall bias, we restrict births in the last 15 years of each survey round.

The DiD approach sketched so far further requires the assumption that selection into having a firstborn boy vs. girl did not change as PSDT became available. We corroborate this assumption in our baseline sample in Table 3, where we report differences in the means of the demographic

[7] To avoid overlapping of male-to-female ratio for pre- and post-ultrasound periods, we use 5-year moving average of years 1990-94, for the years 1993 and 1994 and years 1995-99 for the years 1995 and 1996.

[8] For each index birth, the history of previous births is preserved, even if that history extends across longer than 15 years. We get similar MFR plots when we use a 20-year window. After pooling all four survey rounds and left truncating the fertility data, we are left with 707,837 births between 1985 and 2005.

characteristics of mothers with a firstborn daughter vs. son, for both the pre-and post-1995 samples. We do not find any statistically significant difference in the means of demographic characteristics like mothers' age, age at marriage, age at first birth, marital status, own education, husband's education, religion, and type of residence. This set of balancing tests supports the assumption that the gender of firstborns is as good as random in both time periods.

Table 3: Balancing tests for firstborn girl

	Pre 1995	Post 1995
Age	0.042	-0.002
Age at first marriage	0.003	0.053
Age at first birth	0.018	0.036
Marital status	-0.002	-0.002
Own education		
No education	-0.008	-0.008
Lower Primary (0-4)	0.005	0.000
Upper Primary (5-7)	-0.001	-0.000
Primary Completed (8-9)	0.003	-0.003
Secondary (10-11)	0.005	0.01*
Senior secondary (12 and above)	-0.004	0.002
Husband's education		
No education	-0.009	-0.004
Lower Primary (0-4)	-0.002	-0.002
Upper Primary (5-7)	0.004	0.001
Primary Completed (8-9)	0.011*	-0.002
Secondary (10-11)	0.002	0.002
Senior secondary (12 and above)	-0.006	0.004
Religion		
Hindus	0.004	-0.001
Muslims	-0.003	-0.003
Christians	0.004	-0.001
Others	-0.006*	0.005*
Castes		
SC	0.009*	-0.004
ST	-0.004	-0.000
Other Caste	-0.006	0.005
Urban resident	0.005	0.005
Observations	25387	25224

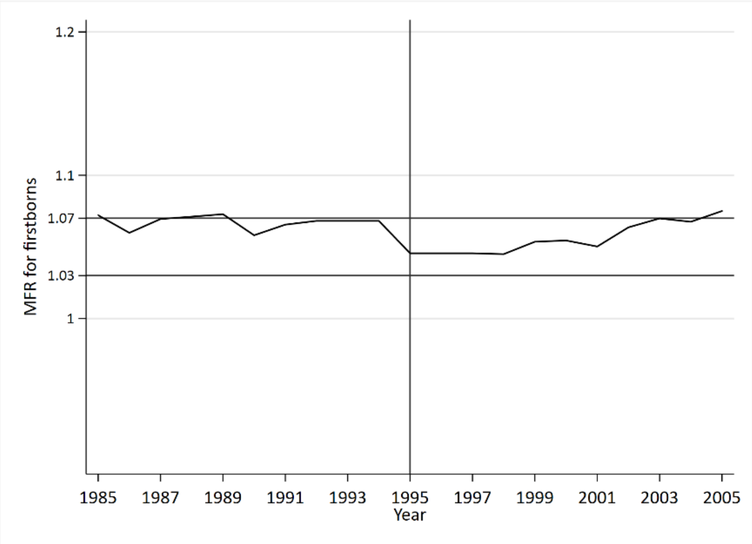
*Note: Each cell reports the coefficient of the firstborn girl dummy in an OLS regression of the characteristic reported in the first column on the firstborn girl dummy. *: p<0.1, **: p<0.05, ***: p<0.01.*

In addition, in Figure 2 we plot the male-to-female ratio (MFR) over time for firstborns using all four rounds of NFHS data.[9] The figure shows that the ratio remains close to the normal range and does not become more male-biased after PSDT became available, consistent with the absence of

[9] As in Figure 1, we pool retrospective birth histories from all the four survey rounds of the NFHS data conducted in 1992-93, 1998-99, 2005-06, and 2015-16, respectively. To limit the recall bias, we restrict births in the last 15 years of each survey round.

changes in selective abortions among firstborns. This evidence is also consistent with the existing literature, which has shown that the sex of firstborn children is as good as randomly assigned (Almond and Edlund, 2008; Anukriti et al., 2022; Bhalotra and Cochrane, 2010; Kugler and Kumar, 2017). While the sex ratio of the oldest child is found to be biologically normal, that of subsequent children is heavily male-biased, especially when there is no previous son.

Figure 2: Male-to-Female ratio at first birth



Note: The figure plots the 5-year moving average of male to female ratio for the firstborns between 1985-2005. The two horizontal reference lines denote the normal sex ratio (from 1.03 to 1.07). The vertical line denotes the structural break in the availability of ultrasound facility in 1995. We use NFHS rounds 1, 2, 3, and 4 conducted in 1992-93, 1998-99, 2005-06, and 2015-16, respectively. To avoid recall bias, we restrict births in the last 15 years of each survey round.

The DiD approach that we have sketched so far would be informative about the causal effect of PSDT on mothers' labour supply under the assumption that there were no firstborn gender-specific shocks that hit at the same time as the PSDT introduction. One such potential shock is the wave of liberalizations that happened in India since the 1980s, which resulted in improved educational attainment of women. In the Indian Census data, the female literacy rate has improved from 29.8% in 1981 to 54.2% in 2001 and 65.5% in 2011. The gap in male-female literacy rate has reduced from 26.64% in 1981 to 21.70% in 2001. For instance, it could be that the spread of progressive ideas led mothers to invest relatively more in their daughters. This trend may have generated negative impacts on the labour supply of mothers of firstborn daughters (vs. sons) even in the absence of the introduction of PSDT.

To overcome this issue, we further distinguish across Indian local areas with high and low 1981 MFR between 0 to 6 years and assume that the availability of PSDT changed firstborn gender-induced sex selection behaviour more markedly in areas with higher son preference before PSDT became available. Under this assumption, the DiD estimate for areas with low son preferences shall mostly capture the secular trends in maternal labour supply by gender of firstborn that would have been observed in high son-preference states in the absence of PSDT-induced sex selection. If we are also willing to assume that these underlying trends have been comparable across low- and high- son-preference states, then the triple-difference estimator that subtracts the DiD estimate obtained in low-son-preference areas from the one in high-son-preference ones identifies the causal effect of PSDT on maternal labour supply.

Several pieces of evidence help us substantiate the assumption that firstborn gender-induced sex selection took place more markedly in high son-preferring areas after PSDT became available. First, in Table 4 we replicate the analysis of Table 2 after distinguishing between regions with above and below median son preference by introducing interaction between the gender of firstborn and standardized MFR in 1981. In columns 1 and 2 we run the regressions separately for pre and post-1995 periods and in column 3 we pool the two periods and introduce a triple interaction. The triple differences estimate on Firstborn girl×Post×Son Pref corroborates that sex selection behaviour was more marked in areas with higher son preference. That is, the probability of sex selection at second births conditional on having a firstborn girl vs. boy after the introduction of PSDT is much larger and significant in areas with high son preference. The triple-differences estimate is not statistically significant in our baseline sample, where we lack statistical power. The estimate is instead statistically significant at the 10% level in the larger auxiliary sample. The two estimates are similar in magnitude.

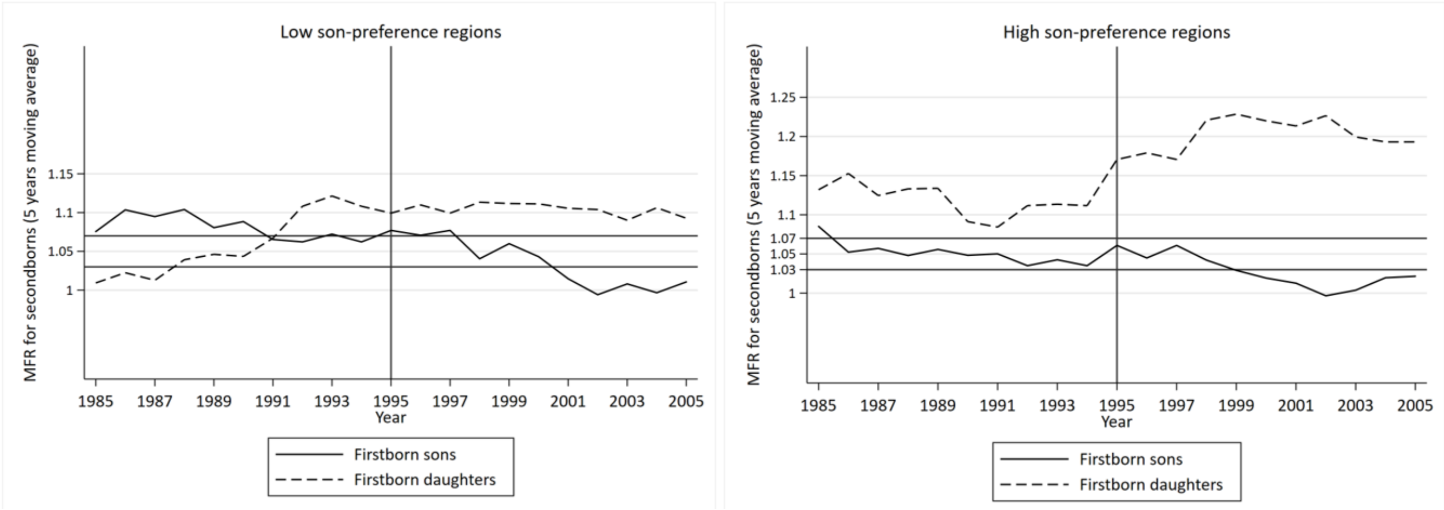
We confirm this finding in Figure 3, where we plot the MFR at second birth by gender of firstborns for areas with a level of the MFR for ages 0-6 in 1981 above vs. below the median. We observe a rather stable gap in MFR at second birth between families with firstborn girls vs. boys in areas with below-median son preference. For areas with above-median son preference, instead, the MFR at second birth diverges significantly between families with firstborn girls vs. boys, and there is a marked increase particularly after 1995.

Table 4: The differential probability of having a boy at the second birth by sex of the firstborn child and local son preference

Dependent variable: male child at second birth	(1) Pre-PSDT	(2) Post-PSDT	(3) Pooled
	Panel A- Main Sample		
Firstborn girl	-0.002	0.032***	-0.0009
	(0.006)	(0.007)	(0.006)
Son Pref	-0.022	-0.027	-0.028*
	(0.016)	(0.03)	(0.016)
Firstborn girl×Son Pref	0.012**	0.022***	0.011**
	(0.005)	(0.006)	(0.005)
Firstborn girl×Post×Son Pref			0.012
			(0.008)
Controls	Yes	Yes	Yes
Observations	14,867	14,344	29,211
	Panel B- Auxiliary Sample		
Firstborn girl	0.00593	0.0248***	0.00584
	(0.005)	(0.005)	(0.005)
Son Pref	-0.007	-0.022*	-0.014
	(0.010)	(0.011)	(0.009)
Firstborn girl×Son Pref	0.013**	0.022***	0.013**
	(0.006)	(0.004)	(0.006)
Firstborn girl×Post×Son Pref			0.009*
			(0.004)
Controls	Yes	Yes	Yes
Observations	59,572	40,616	100,188

Note: See Table 2

Figure 3: Male-to-Female ratio at second birth by gender of the firstborn and local son preference



Note: The figures plot the 5-year moving average of male to female ratio for secondborns by gender of firstborns for low and high son-preference regions separately. The two horizontal reference lines denote the normal sex ratio (from 1.03 to 1.07). The vertical line denotes the structural break in the availability of ultrasound facility in 1995. We use NFHS rounds 1, 2, 3, and 4 conducted in 1992-93, 1998-99, 2005-06, and 2015-16, respectively. To avoid recall bias, we restrict births in the last 15 years of each survey round.

4.2 Estimation

We estimate the following regression equation for mother i from state s surveyed in year t:

$$\begin{aligned} \boldsymbol{Work_{ist}} = {} & \boldsymbol{\alpha + \beta_1 Post_t + \beta_2 FirstGirl_i + \beta_3 SonPref_{i,s}} + \\ & + \boldsymbol{\delta_1 Post_t \times FirstGirl_i + \delta_2 Post_t \times SonPref_{i,s} + \delta_3 FirstGirl_i \times SonPref_{i,s}} + \\ & + \boldsymbol{\gamma\, Post_t \times FirstGirl_i \times SonPref_{i,s} + X_i + \theta_s + \varepsilon_{ist}} \end{aligned} \qquad \textbf{\textit{(1)}}$$

where, $Work_{ist}$ is mothers' labour supply, measured with a dummy equal to 1 if the mother reports to be working at the time of the NFHS interview, and to 0 otherwise; $Post_t$ is an indicator of increased penetration of ultrasound scanners - it takes a value of 1 for mothers with first child born between 1998-06 and 0 for mothers with firstborns between 1985-93; $FirstGirl_i$ is an indicator of a firstborn girl; and $SonPref_{i,s}$ is an indicator of son preference at the local level. We introduce son preferences both linearly and as a dummy variable for areas above or below the median. X_i is a vector of individual characteristics that include indicators for mothers' age, age at first marriage, age at first birth, marital status, education level, husband's education, wealth quintiles, religion, and residence in an urban area. We include state-fixed effects (θ_s) and cluster standard errors by state. The parameter of interest is γ, which captures the triple-differences effect of PSDT availability on mothers' labour supply.

5. Estimation Results

5.1 Effects on mothers' labour supply

Table 5 below reports the estimates for Firstborn girl × Post × Son Preference from a linear probability model with different indicators of son preference at the local level. All specifications include the controls listed in section 4. The triple-differences effect is negative and significant for all the measures of local son preference. For example, the estimate from column 1 suggests that a 1 SD increase in the MFR in 1981 (indicating prevalent son preference) reduces the labour supply of mothers with firstborn girls vs. boys by almost 1.6 percentage points after PSDT became more widely available in 1995.

Next, columns 3 and 4 report the triple-differences estimates when a binary coding of the MFR (above/below median) is used. The estimates indicate that the labour supply of mothers with firstborn girls vs. boys declined by almost 2.3 percentage points after PSDT became more widely available in 1995 in areas with above- vs. below-median MFR.

To gauge the magnitude of the effect on mothers' labour supply, below we present findings from various studies on the effects of different treatments. Several studies explore the relationship between fertility and maternal labour supply in India. Gupta (2020) reports a 9.9pp decrease in maternal labour force participation due to the presence of preschool-aged children (0-5 years). Tiwari et al. (2022), using a Fixed Effects model, find a 1pp significant reduction in maternal labour force participation with an increase in the number of children. Aaronson et al. (2021) examine data from 103 countries (1787-2015) and observe a negative relationship between fertility and maternal labour supply in countries at a later stage of economic development. Using twin IV, they find a negative effect of approximately 5-10pp in India between 1993 and 2005, although statistically insignificant due to limited observations (around 400). Drawing from U.S. data, Angrist and Evans (1998), using gender mix and twin births as instruments, find a 12.5pp and 7.9pp reduction in female labour supply as a result of an additional child, respectively. In Denmark, access to IVF treatment, which induces fertility variation among childless women, leads to reduced labour supply among women (Lundborg et al., 2017). The impact ranges from 7.2pp for mothers with children aged 0-1 years to 4.1pp for mothers with children aged 2-5 years, and 1.5pp for mothers with children aged 6-10 years.

Table 5: Effect of PSDT on mothers' labour force participation

Dep. variable: Mothers' labour force participation	(1)	(2)	(3)	(4)
Firstborn girl × post × z-local MFR in 1981	-0.016*** (0.004)			

Firstborn girl × post × z-growth in state MFR between 1981 and 1991		-0.016***		
		(0.006)		
Firstborn girl × post × above median local MFR in 1981			-0.023**	
			(0.009)	
Firstborn girl × post × above median growth in the state MFR between 1981 and 1991				-0.023**
				(0.010)
Observations	50,611	50,611	50,611	50,611
Mean of Mothers' labour force participation	0.269	0.269	0.269	0.269

*Note: OLS estimated. Additional controls: mothers' age, age at first marriage, age at first birth, marital status, education level, husband's education, wealth quintile, religion, caste, type of residence and state fixed effects. Standard errors are clustered at the state level and are reported in parentheses. *: p<0.1, **: p<0.05, ***: p<0.01.*

We have carried out several tests to verify that our main result on labour supply is robust to various potential empirical concerns. First, in Table A1 in the Appendix, we show that our results are robust when we include controls for state-firstborn birth year and state-firstborn gender fixed effects to assess the likelihood of possible biases due to state-specific time trends and state-specific gender differentials.

Second, in order to enhance the comparability of the samples before and after 1995 and to reduce the share of mothers with multiple births, we replicate our analysis using narrower time intervals around the PSDT introduction date and measuring labour supply for the post-PSDT period with data from the NFHS rounds 2 – carried out in 1998/99, a date that is closer to PSDT introduction. Results in Table A2 in the Appendix are for mothers of firstborns born between 1991-93 and 1997-99, respectively, while those in Table A3 in the Appendix are for the 1990-93 and 1996-99 samples. In both cases, the estimates are comparable to our baseline ones, reported in Table 5.

5.2 Effects on fertility

We next use the same triple-differences strategy used to analyse labour supply to estimate the effect of PSDT on fertility behaviour, using data from our baseline sample. Access to ultrasound technology gave parents the possibility to engage in sex-selective abortions and eliminate any unwanted child, thus, giving them more control over the number as well as the sex composition of children. We investigate whether post availability of PSDT there was a significant change in the number of children, numbers of daughters and sons.

Panel A of Table 6 reports estimates for the fertility behaviour of mothers and shows that access to ultrasound technology increased the number of sons by 0.016, statistically significant at the 1% level. Although statistically insignificant, there is a similar magnitude decline in the number of daughters born by 0.010 and there is no change in the total fertility suggesting the substitution of girls with boys subsequent to the availability of PSDT.

Table 6: Mechanisms linking PSDT and mothers' labour force participation

Outcome Variable	Observations	Triple differences estimate	Std error
	(1)	(2)	(3)
Panel A: Fertility Behaviour			
No. of boys	50,611	0.016***	(0.005)
No. of girls	50,611	-0.010	(0.010)
No. of children	50,611	0.005	(0.010)
Panel B: Changes in Son Preference			
Reported Ideal MFR>1	50,454	-0.001	(0.007)
Standardized reported ideal MFR	50,454	0.003	(0.015)

Note: See Table 5. MFR for children between 0 to 6 years in 1981 is used an indicator of local level son preference.

A potential concern with our estimates on fertility is that the observed results may be driven by changes in son preference over time. We assess this using the following two measures of individual son preference: *i)* a categorical variable on whether the reported ideal MFR is greater than 1; *ii)* the standardized reported ideal MFR. Panel B of Table 6 reports the estimates for these two measures of reported son preference, and shows no effects of PSDT on reported preference towards sons, suggesting that the estimates are not driven by trends in son preference over time.

5.3 Heterogeneity Analysis

We now turn to examine whether the effect of the availability of sex detection technology on mothers' labour-force participation and fertility is heterogeneous across different sub-populations in the sample. We examine if our results differ by women's own educational attainment (below or above the median), their husband's educational attainment, and household wealth (bottom 50% versus top 50%). The triple-difference estimates are reported in Table 7. In each regression, we continue to control for all variables listed in Section 4, except the one used to examine heterogeneity.

The results indicate that PSDT mostly affected fertility as well as the labour supply of educated women, women with educated husbands and belonging to wealthy families, suggesting that there was selection into the use of PSDT by high-SES families.

Table 7: Heterogeneous effects of PSDT on mothers' labour force participation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	N children	N boys	N girls	Work	N children	N boys	N girls	Work
	OWN EDU- BELOW MEDIAN (<=5 years)				OWN EDU- ABOVE MEDIAN (>5 years)			

Triple differences	0.019	0.007	0.009	-0.011	-0.012	0.018*	-0.030**	-0.023**
	(0.013)	(0.009)	(0.014)	(0.007)	(0.015)	(0.010)	(0.014)	(0.011)
Observations	26,755	26,755	26,755	26,755	23,856	23,856	23,856	23,856
Mean	1.987	1.018	0.969	0.325	1.666	0.861	0.804	0.207
	HUSBAND'S EDU- BELOW MEDIAN (<=8 years)				HUSBAND'S EDU- ABOVE MEDIAN (>8 years)			
Triple differences	0.014	0.007	0.007	-0.011	-0.001	0.022*	-0.023**	-0.020**
	(0.014)	(0.009)	(0.018)	(0.006)	(0.011)	(0.012)	(0.008)	(0.008)
Observations	26,502	26,502	26,502	26,502	24,109	24,109	24,109	24,109
Mean	1.944	0.995	0.949	0.318	1.716	0.888	0.828	0.216
	WEALTH BELOW MEDIAN				WEALTH ABOVE MEDIAN			
Triple differences	0.021	0.013*	0.008	-0.009	-0.005	0.017**	-0.022*	-0.026***
	(0.013)	(0.007)	(0.015)	(0.007)	(0.012)	(0.007)	(0.011)	(0.008)
Observations	25,305	25,305	25,305	25,305	25,306	25,306	25,306	25,306
Mean	1.934	0.986	0.948	0.345	1.738	0.903	0.835	0.195

Note: See Table 5. MFR for children between 0 to 6 years in 1981 is used an indicator of local level son preference.

6. Stylized Model

We can summarise the findings from our reduced-form analysis as follows. We have found that labour supply decreases by about 3 percentage points (16% reduction) for wealthy women. Among these women, we detect substitution of daughters with sons after the introduction of PSDT, with no impacts on total fertility. As discussed in the introduction, several mechanisms contribute to explain why this change in fertility behaviour post the introduction of PSDT could have reduced mothers' labour supply. A notable one is dowry payments. Daughters often represent a substantial economic burden in places where parents provide a dowry, and the substitution of girls with boys reduces the needs for mothers to save for dowry payments. In this section, we present a model that serves as a framework to explore how the dowry system can work as a mechanism through which PSDT affects the labour supply of mothers in India.

Model setup

We propose a three-period model ($T = 3$) where each period corresponds with a potential pregnancy. In the first fertile period (*t=1*) all women undergo a first pregnancy and have their first child. Consistent with the observed patterns, women never engage in sex selection at the first birth, and irrespective of the availability of PSDT the gender of the firstborn is thus completely random. We next assume that all women undergo a second pregnancy in the second fertile period (*t=2*). In the absence of PSDT, the gender of the second-born is also random. Instead, when PSDT is available women use the technology with a probability p if the firstborn is a girl. In that case, they obtain a boy for sure.[10] We take the availability of PSDT (and the consequent use of selective abortion) as exogenous, and consistent with the evidence discussed in Section 3 we assume that PSDT use depends on mothers' wealth. Finally, women may choose whether or not to undergo a pregnancy in the third fertile period (*t=3*), and we denote this choice with $N_3 = 1$. This means that the number of children is 1 in t=1, 2 in t=2, and it is equal to $N_c = 2 + N_3$ in t=3. We assume that women never use PSDT in period *t=3*, and the gender of the third-born is thus random.

When a daughter is born, mothers start to save for paying a dowry $d(N_g, N_c, a_0)$ at the end of period *t=3*. The dowry also accounts for the future long-term care cost that mothers will undergo when the daughter moves out of the household after marriage, and is net of potential dowries received from a son's marriage. Therefore, dowry size is a function of the number of girls (N_g) and the total number of children, which depends on the decision to have a third child ($N_c = 2 + N_3$).

Consistent with a large body of evidence, we further assume that dowry size also depends on the initial level of wealth (a_0). Calvi and Keskar (2021) report that the dowry amount is higher for better-off families, with dowry payments in the top ten percent of the wealth distribution being approximately six times the dowry payments in the bottom ten percent. On average, dowries in families at the top of the wealth distribution amount to twice the annual household consumption expenditure for these families; at the bottom of the distribution, they are approximately equal to how much these families spend in a year. Anderson (2007) reports the large variability across different time periods and regions in India ranging from 3 to 8 times annual male earnings. For example, for Delhi, they report dowry between 1920 and 1984 to be 4 times annual male earnings. The assumption that dowry is increasing in wealth is supported also by theoretical reasons by Borker et al. (2022). Under assortative mating on wealth, parents of girls want their daughters to match with wealthier boys and therefore, dowry needs to be sufficiently increasing in wealth to ensure that less wealthy girls' parents do not deviate from the assortative mating equilibrium.

We assume that utility is intertemporally separable, and mothers maximize the discounted value of expected utility over the three periods $\sum_{t=1}^{3} \beta^{t-1} E(U_t)$ and choose optimal consumption (C_t), labour supply (L_t), and whether to have a child in the third period (N_3), subject to an intertemporal budget constraint.

[10] We assume that availability of PSDT coincides with the availability of selective abortion (Anukriti et al., 2022) In Table 2 of this paper, we provide evidence that mothers of firstborn girls are more likely to engage in sex selection than mothers with firstborn boys after the introduction of PSDT.

Equation 2 reports the per-period utility function. Labour supply (L_t) assumes two possible values: not working (0) and working (1). The marginal disutility of work is captured by the parameter ϕ. The term λ denotes the marginal utility from having a third child in period *t=3*. This third pregnancy is also associated with the risk of having a girl and paying a dowry, which is reflected in the budget constraint. $I(.)$ are indicator functions taking the value of one if the argument is true, and ρ is the relative risk aversion parameter.

$$U(C_t, L_t, N_3) = \frac{C_t^{(1-\rho)}}{(1-\rho)} - \phi I_{(L_t=1)} + \lambda I_{(N_3=1)} \tag{2}$$

The budget constraint is

$$a_t = (1+r)a_{t-1} + w(a_0)I_{(L_t=1)} - C_t \qquad for\ \ t = 1,2 \tag{3}$$

$$a_3 = (1+r)a_2 + w(a_0)I_{(L_3=1)} - C_3 + d\big(N_g, N_3\big) \qquad for\ t = 3$$

where a_{t-1} is the stock of wealth at the beginning of period t and r is the risk-free interest rate. In each period a mother can earn a wage $w(a_0)$ if she works; the wage is a function of initial wealth a_0. Wealth is constrained to be non-negative during the first two periods ($a_t \geq 0$ for $t = 1,2$), while at the end of period *t=3* it should be equal to 0 if no dowry is paid or to the opposite of the dowry payment if this needs to be paid, so that $a_3 = \min\Big(0, -d\big(N_g, N_3, a_0\big)\Big)$.

The state variables in our model are initial wealth (a_0), wealth at the beginning of the period (a_{t-1}) and the number of daughters at the beginning of the period, $N_{g,t}$. Mothers differ in their initial level of wealth, which under assortative matching captures heterogeneity in the education level and wealth of fathers.

Timing of the model and calibration

At the start of each period *t*, women observe their level of wealth (a_{t-1}) and the number of daughters they already have ($N_{g,t}$). In period *t=3* only, they decide whether to have a third child. The gender of the newborn, which depends on access to technology, is then revealed, and at that stage, mothers decide whether to work or not. Finally, they choose how much to save for the next period (a_t). In period *t=3*, consumption and saving decisions depend on the dowry payment. If $d(.)$ is positive they increase consumption, if it is negative, they save the necessary amount to pay for the dowry.

We compute the initial wealth of the mother as the present discounted value of the father's lifetime earnings.[11] We assume wages are increasing in initial wealth, meaning that wealthy (and more educated) women earn more conditional on participation. Our parametrization implies that the gender pay gap goes from 2.5 for low-wealth mothers to 1.03 for high-wealth ones.[12] On average, we find evidence that dowry payments correspond to 2 male annual earnings (Chiplunkar and Weaver, 2021). However, this amount shows large variability across families' wealth distribution, time periods, and Indian regions. Consistent with what is discussed above, we assume a dowry function that is increasing in household wealth, with a dowry payment that ranges from 1.5 annual earnings for low-wealth households to 5.6 for high-wealth ones.

The gender realization of the newborn children is drawn from a Bernoulli distribution with parameters set in such a way that the male/female ratio is equal to the natural one, i.e. 1.05. Finally, we set the relative risk aversion parameter to 1.4, the discount factor to 0.93 and the real interest rate to 6%.[13]

We calibrate the remaining parameters – the marginal disutility of work (ϕ) and the marginal utility from the third child (λ) – to match respectively the labour supply before the introduction of the technology (aggregate and by wealth levels) and the average fertility rate (reported in column 1 of Table 9). We assume that PSDT use is exogenous and that PSDT use mirrors the evidence from our reduced form result, showing that the technology has been used mainly by high-wealth mothers. Therefore, the function that governs the exogenous probability of using PSDT is increasing in wealth and calibrated to reproduce the post-intervention sex ratio which is 1.10.[14]

We discretize the state variables (we use a 30-point grid for the wealth variables, a_0 and a_t) and solve the model backwards under two scenarios: with and without PSDT. We then simulate two alternative states of the world: *i)* a scenario in which PSDT is available and *ii)* a scenario without PSDT. The former case is obtained by simulating $p(a_0)$ individuals using the policy functions for the

[11] We use data from India Human Development Survey (IHDS) conducted in 2005 and assume the earnings observed for males between 25 to 55 years are constant over a period of 30 years, and reduce them by 10% to account for possible periods of unemployment. Initial wealth is obtained as the present discounted value of the annual earnings. The initial wealth distribution is in 2005 Indian rupees and the corresponding amount in pounds is reported in Table A5 in the Appendix.

[12] These figures are consistent with data from Shah et al (2015) that shows a gender pay gap in the period considered that is above 2 for blue collar workers and just above 1 for white collar workers.

[13] This corresponds with the average real interest rate observed in India between 1995 and 2005. Source: The World Bank data.

[14] Figure A1 in the appendix shows the Probability of PSDT use as a function of initial wealth. In the baseline model specification we use the blue curve. We also report results for alternative functional form assumption at the end of the model section (yellow and red curves).

model with PSDT and the remaining $1 - p(a_0)$ using the policy functions for the model without PSDT. The latter case uses only the solution obtained from the model without PSDT. We report the baseline calibration in column 1 of Table A6 in the appendix.

The first two columns of Table 9 show that the model can replicate well the targeted moments[15] and the baseline model predicts that the introduction of PSDT caused a 2.5 percentage points reduction in the labour supply of wealthy mothers – a value that is extremely close to the 2.6 p.p. effect delivered by our reduced-form estimates.

An additional mechanism that can reinforce the observed effect driven by the economic burden of dowry payment is the preference for sons, which leads Indian mothers to invest more time and resources in sons than daughters, making the decision to participate in the labour market more costly in the presence of sons. To assess the role of this additional mechanism, we allow the marginal disutility of work to be higher after the birth of the first son. The calibrated parameters are reported in column 2 of Table A6 in the Appendix and the model fit is in column (3) of Table 9. The model replicates the targeted moments equally well and produces a larger effect of PDST introduction on mothers' labour supply (3 pp). We also checked to what extent the difference in the disutility of work alone can generate the observed reduction in participation after the policy introduction. We did it by setting the dowry to zero. The differential cost of work can generate a reduction in labour supply of 1.7 pp, with a cost of work in the presence of a son that almost doubles the cost of work in the presence of girls only.[16]

Table 9: Model fit. Targeted and not targeted moments.

Targeted moments	(1) Data	(2) Baseline calibration	(3) Baseline + gender specific disutility of work
Average labour supply	27%	28%	28%
Average labour supply - wealthy	19%	18%	19%
Average labour supply - poor	35%	37%	37%
Fertility rate	Above 3 in 1995	3	3
Male/female ratio after PSDT introduction	1.10	1.10	1.10
Not targeted moments			
Difference in participation - wealthy	2.6 pp	2.5 pp	3 pp
Difference in participation – poor	0 pp	0.2 pp	0.3 pp

Note: Wealthy and poor are those with wealth above and below the median, respectively. Difference in participation is computed as participation in the scenario without PSDT minus participation in the scenario with PSDT.

[15] Note that the fertility rate cannot be above 3, as a maximum of three pregnancies are possible in the model.

[16] Results are available upon request.

We perform a set of robustness analyses to assess the role of some modelling assumptions. First, we experiment with different functional forms for $p(a_o)$. The corresponding model fits are in columns 3 and 4 of Table A7 in the Appendix and show that our baseline results are broadly confirmed. Second, we use an alternative functional form for wages which implies a less steep variation in the gender pay gap conditional on wealth (from 1.85 to 1.2) and we do not detect important variations in the main conclusions (see column 3 of Table A8 in the appendix). Third, we reduce the variability in dowry payments by initial wealth level and allow them to range from 1.8 for low-wealth mothers to 4.2 for high-wealth mothers. In this case, the effect is smaller in magnitude (see column 4 of Table A7) and reduces to a 2 percentage point decrease in mothers' labour supply, suggesting that dowry payments increasing in wealth is a key mechanism in our model.

7. Conclusion

With the liberalization of the Indian economy and following the acceleration of the domestic production of ultrasound machines, since the mid-1990s Indian households experienced a sudden increase in the availability of prenatal sex detection technology (PSDT). The low cost and the non-invasive nature of ultrasound scans led to their widespread use for fetal sex determination. Due to the stark preferences of Indian families towards having sons, this resulted in a staggering rise in female feticide and eventually, an increase in the male-to-female sex ratios at birth from 964 girls born for every 1000 boys in 1971 to 927 girls in 2001. The resulting scarcity of girls has been found to have consequences on violence against women, marriage market imbalance, prostitution, and sexually transmitted diseases, among others. In this paper, we investigate the effect of the wider availability of PSDT on mothers' labour supply in India.

Using a triple-differences approach, we exploit supply-driven changes in the availability of ultrasound technology interacted with the quasi-random family-level incentive to conduct sex selection and local-level proclivity to carry out sex selection. We find that the increased availability of PSDT has led to a reduction in mothers' labour supply.

Exploration of channels linking prenatal sex selection and mothers' labour supply shows that access to PSDT gave mothers more control over the sex composition of children. We find that subsequent to the availability of PSDT there was an increase in the number of sons and a similar reduction in the number of daughters, suggesting that daughters were selectively aborted and replaced with sons.

We find that the changes in fertility behaviour and women's labour supply due to PSDT are driven by educated women, women with educated husbands and belonging to wealthier families suggesting that more girls were aborted in high-SES families.

We identify two potential mechanisms: (i) an income effect driven by a reduction in the average dowry payments due to the change in the sex composition of children, (ii) an increase in the disutility of work: the existing literature documents that Indian mothers invest more time in sons than daughters and in response to having more sons in the family mothers reduce their labour supply.

We develop a model of fertility and labour supply of mothers and solve it in two states of the world, with and without PSDT. We then simulate from the models by allowing an exogenous fraction of individuals to access PSDT. The model embeds both mechanisms listed above, dowry payments and disutility of work which depends on newborn gender. We find that dowry alone can generate the reduction in labour supply we identified in the reduced form estimates. Son preference reinforce the negative effect on labour supply but, alone, cannot generate the estimated reduction in labour supply.

Model implications are robust to the change in some modelling assumptions: the functional form of the wage function - which depends on wealth, and the functional form of the exogenous access to the technology – which also depends on wealth. The negative effect on labour supply of PSDT introduction is lower (2 pp) when we reduce the steepness of the dowry as a function of wealth, suggesting the importance of this assumption, which rests on empirical evidence from the literature.

8. References

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9. Appendix

Table A1: Robustness check- controls for state-time and state-firstborn gender fixed effects

Dep var-Mothers' labour force participation	**(1)**	**(2)**
Firstborn girl × post × z-local MFR in 1981	-0.018***	
	(0.004)	
Firstborn girl × post × z-growth in state MFR between 1981 and 1991		-0.017**
		(0.006)
Observations	50,611	50,611
Mean	0.269	0.269

*Note: Robustness check- Specification controls for state-time and state-firstborn gender fixed effects. All the specifications control for mothers' age, age at first marriage, age at first birth, marital status, education level, husband's education, wealth quintiles, religion, caste, type of residence and state-fixed effects. Standard errors are clustered at the state level. and are reported in parentheses. *: p<0.1, **: p<0.05, ***: p<0.01.*

Table A2: Robustness check- Sample of mothers with first births between 1991-93 and 1997-99

Dep. variable: Mothers' labour force participation	**(1)**	**(2)**
Firstborn girl × post × z-local MFR in 1981	-0.021**	
	(0.009)	
Firstborn girl × post × z-growth in state MFR between 1981 and 1991		-0.022**
		(0.009)
Observations	13,523	13,523
Mean	0.226	0.226

*Note: Robustness check- Regressions include mothers with first births in 1991-93 and 1997-99 from NFHS rounds 1 and 2, respectively. All the specifications control for mothers' age, age at first marriage, age at first birth, marital status, education level, husband's education, wealth quintiles, religion, caste, type of residence and state-fixed effects. Standard errors are clustered at the state level and are reported in parentheses. *: p<0.1, **: p<0.05, ***: p<0.01.*

Table A3: Robustness check- Sample of mothers with first births between 1990-93 and 1996-99

Dep var-Mothers' labour force participation	(1)	(2)
Firstborn girl × post × z-local MFR in 1981	-0.016*	
	(0.009)	
Firstborn girl × post × z-growth in state MFR between 1981 and 1991		-0.019***
		(0.006)
Observations	19,382	19,382
Mean	0.234	0.234

*Note: Robustness check- Regressions include mothers with first births in 1990-93 and 1996-99 from NFHS rounds 1 and 2, respectively. All the specifications control for mothers' age, age at first marriage, age at first birth, marital status, education level, husband's education, wealth quintiles, religion, caste, type of residence and state-fixed effects. Standard errors are clustered at the state level and are reported in parentheses. *: $p<0.1$, **: $p<0.05$, ***: $p<0.01$.*

Table A5: Distributions of initial wealth (rupees and pounds, 2005 prices)

Percentiles	10 pct	25 pct	50 pct	75 pct	90 pct	95 pct	99 pct
Rupees	101697.687	195980.501	383948.457	812236.7	1568890	2241271	4034288.4
Pounds	1287.312	2480.766	4860.107	10281.48	19859.37	28370.52	51066.94

Table A6: Calibrated parameters. Baseline and alternative specifications

Calibrated parameters	(1) Baseline calibration	(2) Disutility of work	(3) Functional form 1	(4) Functional form 2
ϕ – marginal disutility of work	0.02	0.0185	0.02	0.02
λ – marginal utility of third child	0.05	0.05	0.05	0.05
b – curvature of the $p(a_0)$ function	2	2	12	-
a^* – level of wealth at which $p(.)$=1	99^{th} pct	99^{th} pct	95th	90^{th} pct
ϕ_B – marginal disutility of work after first son birth	-	0.0205	-	-

Note: Disutility of work allows ϕ to be higher after first son birth (ϕ_B); Functional form 1 uses the curve labelled rob1 in Figure A1; Functional form 2 uses the curve labelled rob2 in Figure A1.

Table A7: Model fit. Targeted and not targeted moments. Sensitivity to model assumptions

Targeted moments	(1) Data	(2) Baseline calibration	(3) Functional form 1	(4) Functional form 2
Average labour supply	27%	28%	28%	27%
Average labour supply - wealthy	19%	18%	19%	18%
Average labour supply - poor	35%	37%	37%	37%
Fertility rate	> 3 in 1995	3	3	3
Male/female ratio after PSDT introduction	1.10	1.10	1.10	1.11
Not targeted moments				
Difference in participation - wealthy	2.6 pp	2.5 pp	3 pp	3 pp
Difference in participation – poor	0 pp	0.2 pp	0.3 pp	0.2 pp

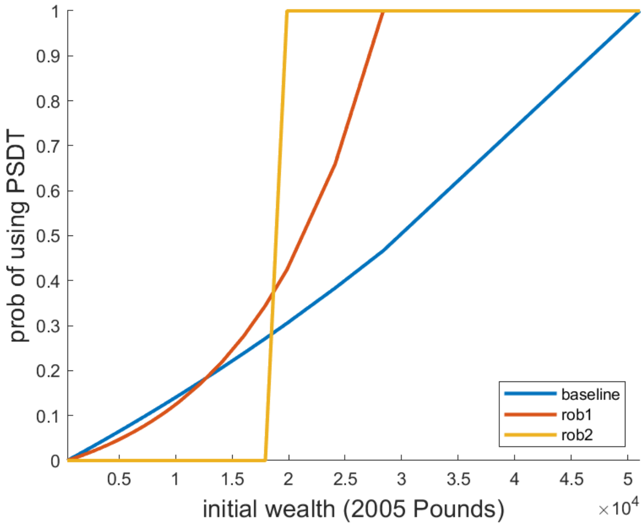
Note: Wealthy and poor are those with wealth above and below the median, respectively. Functional form 1 uses the curve labelled rob1 in Figure A1; Functional form 2 uses the curve labelled rob2 in Figure A1.

Table A8: Model fit. Targeted and not targeted moments. Sensitivity to model assumptions

Targeted moments	(1) Data	(2) Baseline calibration	(3) Wage function	(4) Dowry function
Average labour supply	27%	28%	26%	28%
Average labour supply - wealthy	19%	18%	18%	18%
Average labour supply - poor	35%	37%	34%	38%
Fertility rate	Above 3 in 1995	3	3	3
Male/female ratio after PSDT introduction	1.10	1.10	1.10	1.10
Not targeted moments				
Difference in participation - wealthy	2.6 pp	2.5 pp	2.5 pp	2 pp
Difference in participation – poor	0 pp	0.2 pp	0.3 pp	0.3 pp

Note: Wealthy and poor are those with wealth above and below the median, respectively.

Figure A1: Probability of PSDT use as a function of initial wealth. Baseline model and alternative specifications



The functional form of the probability of using PSDT is reported below:

$$p(a_0) = \min \left(b^{a_0/a^*} - b^{\underline{a}/a^*} \big/ b - b^{\underline{a}/a^*}, 1 \right)$$

Where a^* is the level of wealth above which the probability is one, $\underline{a}$ is the minimum level of wealth, and b is a parameter that determines the curvature of the function. In the case of the second alternative specification (rob2 in Figure A1), $p(a_0)$ takes value 0 if wealth is below the 90th percentile and 1 otherwise.