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Health consequences of sterilizations

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Abstract: One-third of married women are sterilized in India. This is largely due to family planning programs that put a strong emphasis on 'permanent' contraceptive methods rather than temporary ones. However, little is known about potential adverse effects on women's wellbeing. We analyse the consequences of sterilization on maternal health. To do so, we take advantage of datasets that record information on various symptoms in the reproductive sphere or anthropometric and biological measurements. In order to deal with endogeneity issues, we exploit two features of the sterilization decision. First, households have a son preference and women are more likely to be sterilized when their first-born is male. Second, Indian households face different malaria prevalence. Being sterilized involves taking the risk of losing one child in infancy and not being able to replace him or her. As a consequence, women tend to postpone sterilization in areas with more malaria. We exploit the fact that the increase in sterilization associated with a male first-born decreases with malaria prevalence. We show that sterilization strongly increases the prevalence of various symptoms in the reproductive sphere (from +50 per cent for vaginal discharge to more than 100 per cent for pain or problems during sexual intercourse, for instance). However, we also find that sterilization leads to improvements in BMI and haemoglobin levels, likely from the avoidance of pregnancies.

Keywords: development, fertility, gender, health, sterilization
JEL classification: I15, J13, O1, D1

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1 Introduction

In November 2014, 12 Indian women died after mass sterilizations in Chhattisgarh, after the surgeon had carried out 80 sterilizations in five hours. In India and in many other developing countries,[1] female sterilization is the main contraception available to households who wish to manage their fertility. India spends as much as 85% of its family planning budget on female sterilization,[2] and one-third of married women are sterilized.[3] Such a strong emphasis on one specific contraceptive suggests that Indian family planning is a one-size-fits-all approach. While the demographic side of development has been widely debated among economists, our discipline is almost silent about the best way to control fertility in a poor country. In particular, all contraceptives are not equivalent in terms of required care, side effects and changes they induce in women's status within the household. This paper analyzes the impact of sterilization on maternal health, as a potential hidden cost of fertility control. We do so by using very comprehensive datasets on health and by implementing an identification strategy that relies on exogenous variation in women's willingness to be sterilized.

Our paper is related to several strands of literature. First, from a public health perspective, we provide an assessment of the costs/benefits of getting sterilized. Wickstrom and Jacobstein (2011) show that the cost of contraception per year of protection for a couple is higher when the couple opts for sterilization rather than non-permanent methods, such as intra-uterine devices.[4] If this is the case, then female sterilization has to provide other relative benefits to compensate for the increased cost.

Second, the medical literature has already studied the side effects of contraceptives. While the risks associated with the surgery itself are minor if sanitary conditions are met,[5] sterilization might have several side effects. The main consequences explored by the medical literature are related to the disturbance of the ovarian function and to various menstrual and menopausal symptoms. This might imply menstruation abnormality,

[1] For instance, Dominican Republic, Panama, Salvador, Guatemala, Colombia, Nepal, Brazil, Nicaragua and China.

[2] 80% of this amount was spent on incentives and compensations, rewarding the person who was undergoing the operation, the motivator who brought her to the facility, and the facility staff (Population Foundation of India et al., 2014)

[3] Figure computed on the 2002–2004 and 2007–2008 District Level Household Surveys.

[4] A female sterilization is estimated to cost \$4 per year, which amounts to the cost of the cheapest reliable implants, and is more expensive than intra-uterine devices (\$1.75) and vasectomy (i.e. male sterilization, \$2.25).

[5] India seems however unable to guarantee safe sanitary conditions during surgery. Between 2009 and 2012, the government of India paid compensation for 568 deaths due to sterilizations. Source: *The Guardian*, quoting an answer of the Health Ministry to a parliamentary question in 2012. `https://www.theguardian.com/world/2014/nov/12/india-sterilization-deaths-women-forced-camps-relatives`. This aspect of the sterilization policy cannot be documented in our paper due to lack of data.

menstrual pain and dysfunctional uterine bleeding. Desai et al. (2014) focus on a sample of 150 Indian women with abnormal uterine bleeding in Gujarat, India, and show that women who have undergone bilateral tubal ligation are more likely to suffer from dysfunctional uterine bleeding. However, they rely on a small sample which is highly selected. Gentile et al. (1998) have provided an extensive literature review on the medical effects of sterilization. Their main conclusion is that studies are contradictory, and provide no evidence of post-tubal litigation syndrome. However, the existing studies are plagued by two main limitations. First, most are based on very small samples. Second, they fail to account for economic characteristics which are often associated with sterilization (like wealth and education) and do not recognize that sterilization is a choice and therefore might be endogenous to any health outcome.

Beside these physiological health effects, sterilization might also harm psychological and emotional health. Sterilization is theoretically reversible, but in practice it is rarely the case, either for technical reasons or for cost reasons. This irreversibility could generate emotional distress if women regret the operation. Hillis et al. (1999) followed a sample of 11 000 American women sterilized between 1978 and 1987 and found that 20% of the women sterilized at age 30 or younger expressed regrets within 14 years after sterilization. On a sample of 31 000 Indian women, Singh et al. (2012) observe that regrets tend to increase five years after the sterilization, and are higher after the loss of a child. Regrets might be even more likely if sterilization is not the result of a fully informed choice. Balasundaram (2011) reports numerous coercions performed by the health sector on women working in tea plantations in Sri Lanka, while Singh et al. (2012) stress that in India women from scheduled tribes and Muslim women were more likely to express regrets after sterilization. Poverty might fuel regrets if the operation has been accepted because of the payment involved. Bharadwaj (2015) shows that the decision to undergo sterilization is affected by cash incentives.

Third, sterilization affects other crucial dimensions of a woman's life. The most obvious one is her ability to manage her fertility. While sterilization could be substituted by other types of contraceptives and therefore have only a limited effect on actual fertility, Bharadwaj (2015) has shown that sterilization reduces the number of children: he estimates that getting sterilized leads the women to have on average 0.81 fewer living children. A reduced family size might increase income per capita and increase the ability to pay for health care. In addition, Francavilla and Gianelli (2011) show that family planning policies have a significant and positive effect on the employment of women in India. At the same time, informational frictions characterizing rural labor markets might be better mitigated by a greater family size, especially in the completion of tasks for which worker output and effort are difficult to observe. Bharadwaj (2015) shows that larger families have an advantage over small families in this respect and face reduced supervision costs.

Last, sterilization might also affect the bargaining power of women and hence their access to household resources. Again, the direction of the effect is ambiguous. In general, access to family planning is a vector of women's empowerment. Säävälä (1999) shows that young women might adopt early sterilization to enhance their social status with respect to their mother-in-law. Ebenstein et al. (2013) also conclude that family planning improved women's bargaining power in China. To the contrary, Anukriti and Persson (2014) highlight how female sterilization increases spousal violence. Given these various elements, the effect of sterilization on maternal health is clearly ambiguous and needs to be empirically estimated.

Since sterilization has been so scarcely documented in the economic literature, we start by providing a comprehensive description of the history of family planning policies in India, of the current use of contraceptives, of the spatial heterogeneity of sterilization and of the self-assessed side effects of this surgery. Second, we implement an instrumentation to account for the likely endogeneity of the choice to get sterilized. Namely, we exploit both preference for sons and the fact that sterilization is postponed by women when they fear losing a child. Having a male first-born and facing infant mortality are two determinants of the decision to get sterilized. While neither of these two variables satisfy the conditions to be valid instruments, the interaction between the two, combined to village fixed effects, satisfy the exclusion restriction we need to identify the effect of sterilization on maternal health. We find that the prevalence of various symptoms in the reproductive sphere and pain during sexual intercourse increase by 50% to more than 100% as a consequence of sterilization, but that sterilization also increases women's BMI and hemoglobin levels, likely from a reduction in the number of pregnancies. We also show that the adverse effects of sterilization take time to materialize (three years) and then remain steady. The sterilizations performed in camps are also associated to more adverse effects.

The paper is structured as follows. Section 2 presents the data, and female sterilization in India is described in Section 3. Section 4 describes the identification strategy and Section 5 provides the results.

2 Data

2.1 DLHS

The District Level Household Survey (DLHS 2) collected in 2002–2004 has several strengths that make it highly suitable for our study.[6] First, the survey is representative of the national population and the sampling rate is high: we observe on average 850 households per district. Second, for one woman in the household, the data includes very detailed information on her pregnancy history, her contraception and her fertility choices, including whether she has undergone sterilization and when. This dataset thus offers the opportunity to explore both short-term and long-term effects of sterilization. Third, an extensive health module records detailed information on symptoms in the reproductive sphere. However, the health information collected is only based on self-assessment. This might create some biases, and we return to that later.

2.2 DHS

We complement the previous dataset with the Demographic and Health Surveys (called "National Family and Health Surveys" in India) that were collected in 1998–1999 (DHS 2). They are particularly interesting from the health perspective since they collect anthropometric and biological measurements of women: height, weight and hemoglobin.[7] We know health is a multidimensional concept, and this information, coupled with the DLHS recording of symptoms, will allow us to offer a comprehensive view of women's health. The hemoglobin measurement is of particular interest since most Indian women are anemic. As the DLHS, the DHS is representative of the national population, but the sampling rate is lower. The DHS also records past history of pregnancies and sterilization status of women.

3 Female sterilization in India

3.1 History of Indian family planning

Family planning policies have a long history in India. In 1952 began what would become the largest government sponsored family planning program in the world. Cash incentives were introduced in 1967, while the program gradually expanded. Sterilization policies

[6] We do not use more recent DLHS for the following reason: in DLHS 3, the full birth history of women is not collected, which is necessary for our identification strategy; in DLHS 4, only some states were surveyed.

[7] We do not use the DHS 1 because there are no health measurements for women; and we do not use DHS 3 because we cannot identify districts, which is necessary for our instrumentation.

were promoted by Indira Gandhi in 1976 in order to reduce demographic growth and facilitate economic take-over. Forced sterilization campaigns were implemented in 1975–1977, mainly targeting males. The coercion and the violence involved left profound scars.

In the 1980s, the family planning program continued on a voluntary basis, and shifted towards targeting women. In 1981, a centrally sponsored scheme was launched. Individuals getting sterilized would receive cash incentives, while the medical facilities where the operation was performed would receive additional funds. Typically, the compensation package provided cash to the individual accepting sterilization (the "acceptor"), to the various actors involved in the operation (surgeon, anesthetist, staff nurse, technicians), and later to the person who convinced him or her to accept (the "motivator"). It also included subsidies for private accredited facilities.

The detail of the breakdown was left to the states, provided that some minimum amounts would be paid to the acceptors and used by the medical facilities (for instance, for tubectomy, acceptors should receive at least Rs 150, and a minimum of Rs 60 had to cover drugs and dressing in the facility). IUD insertions were included in the package, involving a transfer of Rs 20 to the medical facility in order to cover actual costs, but nothing for the acceptor.

The package's composition has differed by states and, later on, by population category. In 2001, an "Empowered Action Group" (EAG) was set up in order to develop programs in eight states,[8] which not only ranged among the poorest states of India, but displayed as well the highest population growth of the country. In these states, compensation packages for female sterilization were increased. Some states also created special funds in order to pay ex-gratia to the acceptor of sterilization or her relatives in case of death, incapacitation, or treatment of post-operative complications.[9] In the early 2000s, the number of claims for compensation after failure of sterilization or complications faced by government doctors contributed to various measures aiming at improving the quality and the enforcement of sterilization procedures (Ministry of Health and Family Welfare, 2005). It also led to the creation of a Family Planning Insurance Scheme in 2005, providing indemnity insurance covering doctors and health facilities in case of failure or complications due to the operation.

Additional increases have followed in 2006, 2007 and 2014. In 18 states (the "High Focus States"[10]), the increase was unconditional, regardless of acceptor characteristics. In the other states, the increase targeted only individuals below the poverty line or belonging

[8] The eight EAG states are Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh and Uttaranchal (named Uttarakhand since 2007).

[9] Rs 50 000 in case of death, Rs 30 000 in case of incapacitation, Rs 20 000 in case of complications.

[10] The High Focus States are Bihar, Uttar Pradesh, Madhya Pradesh, Rajasthan, Jharkhand, Chhattisgarh, Uttarakhand, Orissa, Jammu & Kashmir, Himachal Pradesh, Assam, Arunachal Pradesh, Manipur, Mizoram, Meghalaya, Nagaland, Tripura and Sikkim.

to a scheduled caste or a scheduled tribe. In 2014, the compensation package was further increased in the 11 states with the highest fertility rate.[11]

Today, the cash incentive associated with a sterilization varies from Rs 250 (for individuals above the poverty line getting sterilized in a public facility in a non High Focus State) to Rs 1400 (for anybody getting sterilized in a public facility in one of the 11 states previously mentioned).[12] This ranges from PPP$15 to PPP$82. It is called a "compensation" because it is supposed to compensate women for the time lost during their post-sterilization recovery. Despite the fact that the Indian government tries to adopt a more diverse approach to family planning,[13] the main trend is not yet reversed.

Since 2006, community health workers do not get a fixed salary for their activity but are only paid according to their results, which includes convincing women to get sterilized. In total, a sterilization performed in a High Focus State costs at least Rs 2000 (taking into account all the payments that are made by the state but not spending associated with maintaining the health care system more generally), which is roughly PPP$118. If it offers contraception for 20 years, it costs broadly PPP$5.8 per year. Despite the fact that sterilization payments have varied over time and by location, it is worth mentioning immediately that we will not exploit this variation for the two following reasons. Even though there was variation, it was actually common to a large number of states, states being grouped in two main categories. As a result, the variation is very limited. The second important issue is that such changes in policy occurred together with other health policy reforms.[14]

3.2 Use of contraceptives

As a result of this major policy focus on female sterilization, it is by far the most widely used method in the country; 31% of the surveyed women in DLHS 2 are sterilized. While half of the surveyed women report that their couple uses a contraception method, sterilization is used by 62% of them. Table 1 presents the different contraceptive methods used by couples at the time of the survey. Condoms are used by 5% of the respondents, while traditional methods (mostly periodic abstinence and withdrawal) are used by 7% of the couples. Male sterilization is chosen by less than 2% of the couples.

[11]Bihar, Uttar Pradesh, Madhya Pradesh, Rajasthan, Jharkhand, Chhattisgarh, Uttarakhand, Orissa, Assam, Haryana and Gujarat.

[12]Sterilizations done within seven days after delivery involve an extra payment of Rs 600. Payments obtained in accredited private facilities depend on the facility.

[13]For instance, the new scheme also included the promotion of IUDs, and compensation received for vasectomy increased. Source : `http://www.thehindu.com/sci-tech/health/policy-and-issues/gendered-approach-to-sterilisation/article6742284.ece`.

[14]For instance, each time cash incentives associated with female sterilization were raised, cash incentives for IUDs and male sterilization increased as well.

Table 1: Contraception method currently used by women

	Percentage of women		
Any method of contraception used?	All women	Among women having given birth	Among women who have not given birth
Female sterilization	31.3	35.21	0.33
Vasectomy	0.84	0.93	0.13
No-scalpel vasectomy	0.09	0.1	0.02
IUD/copper-T/loop	2.2	2.47	0.04
Oral pills	3.87	4.28	0.63
Condom/Nirodh	5.18	5.64	1.55
Rhythm/periodic abstinence	4.15	4.53	1.12
Withdrawal	2.45	2.66	0.8
Other modern method	0.2	0.22	0.02
Other trad. method	0.52	0.58	0.04
No method - non-pregnant women	40.41	36.61	70.51
No method - pregnant women	8.79	6.77	24.81
Total	100	100	100
Observations	507 622	450 663	56 959

Sample: surveyed women in DLHS 2. Source: authors.

The sample of interest is women who have already given birth, as few women will undergo sterilization before giving birth. As Table 1 shows, women who have not given birth are most likely not using any contraception method. Only 4.7% live in couples using contraception (mostly condoms and periodic abstinence) and 0.3% report being sterilized. In what follows, percentages will be computed for the population of women who have already given birth; "non-sterilized women" will refer to women who have already given birth and are not sterilized.

3.3 Spatial heterogeneity, age at sterilization and place where it was performed

There is a large spatial heterogeneity as regards the use of the various contraceptive methods and the facility where they are made available to women. Figure 1a reports the percentage of sterilized women in our sample of interest, by district.

While in some states in the north-east of India (like Uttar Pradesh), the district average is below 20%, in numerous districts located in the center and in the south-east more than 60% of women are sterilized. In several districts of Andhra Pradesh, the percentage rises above 70%.

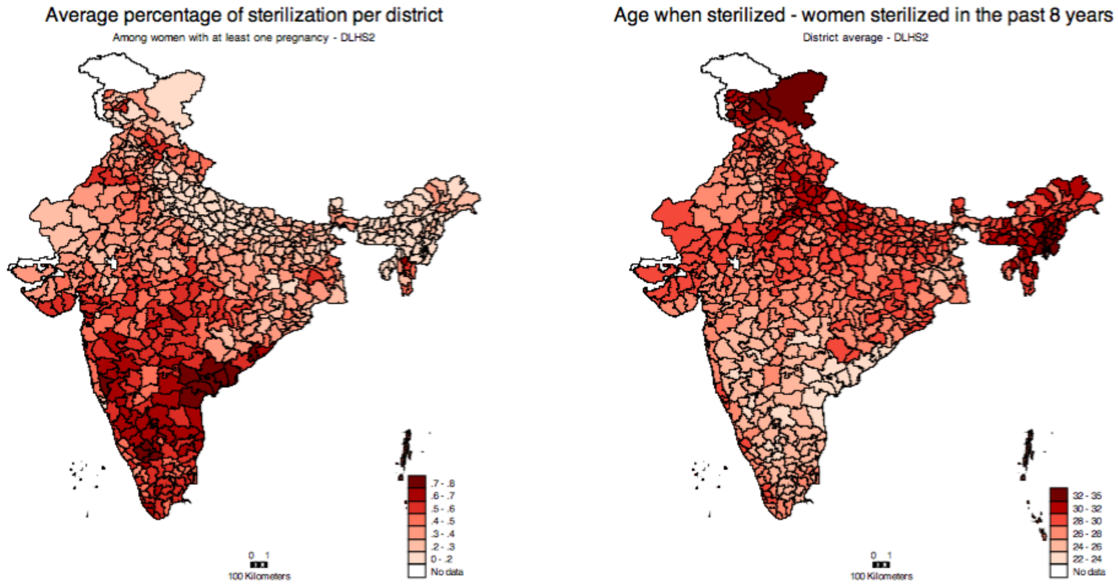
For women who have been sterilized less than eight years before the survey, it is possible to know at what age sterilization occurred.[15] Table 2 displays the number of years

[15] The survey reports when the sterilization was performed, unless sterilization occurs more than eight years ago.

Figure 1: Characteristics of sterilization by district

(a) Percentage of sterilized women

(b) Average age at sterilization



Sample for the left figure: women who have given birth in DLHS 2.
Sample for the right figure: sterilized women in DLHS 2.
Source: authors.

since sterilization in our sample and the average age at sterilization for the subsample of women who were sterilized less than eight years ago. The average age at sterilization is 27 years old and is stable. This hides a considerable diversity in age at sterilization. Actually, 10% of the sterilized women are sterilized under or at the age of 21 and 40% are younger than 25 years old. Figure 1b maps the average age at which women have been sterilized. Women living in the central and southern part of India are sterilized much younger than elsewhere. The lowest district averages lie below 26 years old.

Table 3 reports where the sterilization took place. While 53% of women went to a public hospital, around 19% went to a public health center; 12.5% of women were sterilized in a camp or in a mobile clinic, and 13.8% went to the private sector. This might have implications both for the quality of the health care provided and the likelihood for women to receive any follow-up care. Only a minority (28%) of women sterilized in a public hospital report any care (Table 3, column (2)). Women sterilized in camps appear more likely to have received follow-up but they are also more likely to report health problems because of the sterilization (Table 3, column (3)).

Again, there is a considerable spatial heterogeneity regarding the facility where women were sterilized. Figures 2a and 2b show the proportion of women going to a public hospital or to a camp, respectively. In the northern and the southern tips of India, the vast majority of women (more than 75%) go to public hospitals. In central states, like

Table 2: Time since sterilization and age at sterilization

Years since sterilization	Percentage	Age at sterilization	
		Mean	Median
0	7.78	27.64	27
1	7.25	27.13	27
2	6.99	27.15	27
3	7.68	27.25	27
4	6.91	27.35	27
5	7.43	27.41	27
6	5.51	26.97	27
7	4.03	26.55	26
8	46.44		
Total	100	27.20	27
Observations	153 770	82 364	82 364

Sample: sterilized women in DLHS 2. Source: authors.

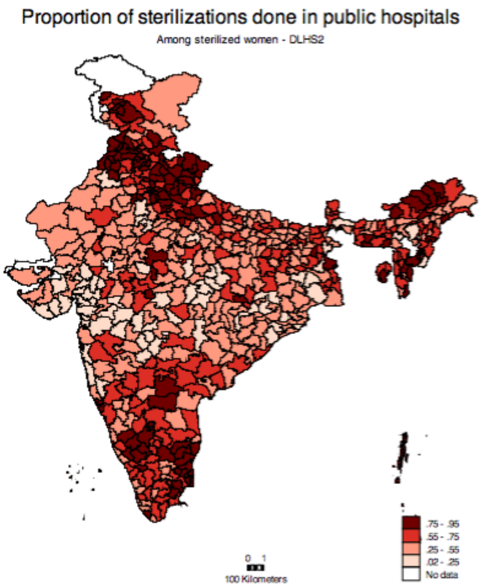
Table 3: Facility where sterilization took place, follow-up and reported problems

Facility	Percentage	Follow-up after sterilization (%)	Mention problems due to sterilization (%)
Public hospital	53.1	28.4	14.8
CHC/PHC	19.4	42.2	19.6
Camp/mobile clinic	12.2	52.6	23.5
Private sector	13.8	14.8	12.9
Other	1.5	24.9	19.1
Total	100	32	16.6
Observations	158 526	158 439	158 475

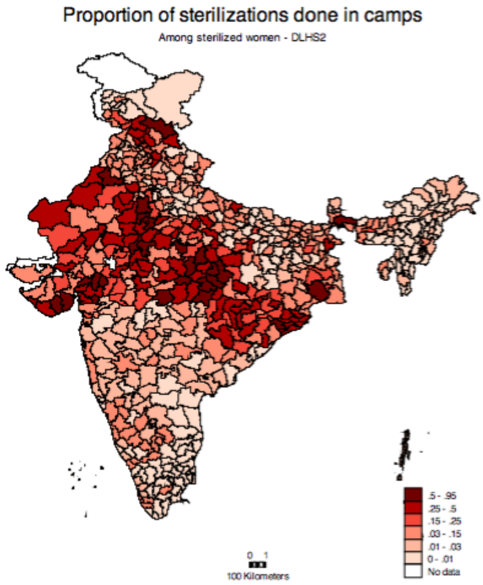
Sample: sterilized women in DLHS 2. Source: authors.

Figure 2: Facility where sterilization took place

(a) Proportion of sterilizations done in a public hospital



(b) Proportion of sterilizations done in camps



Sample: sterilized women in DLHS 2.
Source: authors.

Rajasthan, Madhya Pradesh, Chhattisgarh and West Bengal, women are more likely to be sterilized in camps than are women in the rest of the country. The percentage of sterilizations performed in camps is well above the national average, with sometimes 50% to 80% of sterilized women being sterilized in camps.

3.4 Individual determinants of sterilization

Sterilized women differ from the other women along various characteristics (see Table A1 in the Appendix). They are less educated than others (3.7 years versus 4.7 years for non-sterilized women) but are wealthier,[16] are more likely to be Hindu (84% are Hindu, while Hindus account for 77% of the total population), and to belong to a scheduled caste. They are also more likely to have had a male as their first-born child.

However, these statistics might be driven by the spatial heterogeneity already discussed. We now turn to a regression of the probability of being sterilized on various socio-economic characteristics, controlling for various areas' fixed effects (from none, to state fixed effects, to district fixed effects, to village fixed effects). In the sample of women having already given birth, sterilization is not correlated with wealth (column (1) of Table 4). After the inclusion of fixed effects at the state level (column (2) of Table 4) or district level (column (3)), the correlation becomes negative. Wealth seems to affect

[16] We build a wealth index based on housing characteristics and ownership of durable goods.

Table 4: Probability of being sterilized

	Dependent variable : woman has been sterilized					
	(1)	(2)	(3)	(4)	(5)	(6)
Age	0.021***	0.021***	0.021***	0.021***	0.020***	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Muslim	-0.160***	-0.136***	-0.135***	-0.110***	-0.131***	-0.133***
	(0.00)	(0.02)	(0.01)	(0.00)	(0.00)	(0.00)
Christian	-0.095***	-0.016	-0.013	-0.018***	-0.011*	-0.000
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Sikh	-0.056***	0.011	-0.007	-0.045***	-0.045***	-0.036***
	(0.00)	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)
Buddhist	-0.070***	-0.079***	-0.030***	-0.037***	-0.031***	-0.023**
	(0.01)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
Other religion	-0.120***	-0.019	-0.037***	-0.034***	-0.023***	-0.014**
	(0.01)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
Scheduled caste	0.032***	0.013	0.011**	0.010***	-0.012***	-0.020***
	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)
Scheduled tribe	-0.044***	-0.054***	-0.049***	-0.021***	-0.042***	-0.046***
	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Oth. backw. caste	0.044***	0.025**	0.025***	0.024***	0.008***	0.003
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Wealth	-0.000	-0.010*	-0.011***	-0.011***	0.005***	0.005***
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Education					-0.011***	-0.006***
					(0.00)	(0.00)
Husband edu.					-0.001***	-0.000
					(0.00)	(0.00)
Age of couple						0.021***
						(0.00)
Observations	444 522	444 522	444 522	444 522	440 627	440 626
State FE	No	Yes	-	-	-	-
District FE	No	No	Yes	-	-	-
Village FE	No	No	No	Yes	Yes	Yes
Adjusted R2	0.112	0.117	0.120	0.120	0.129	0.143

Sample: women who have already given birth in DLHS 2. Reference category for religion: Hindu. Reference category for castes: higher castes. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: authors.

negatively the likelihood of being sterilized. This effect however changes sign after controlling for the education level of the woman (column(4)). Less educated women are more likely to accept sterilization. The negative coefficient of wealth was due to the correlation between wealth and education. Conditioning on education, wealthier women are in fact more likely to get sterilized (column (5)).

We run separate regressions by caste and by religion to further explore the characteristics of sterilized women within groups. Tables A2 and A3, in the Appendix, display the results; all regressions include village fixed effects.

Most of the correlations described above are observed within groups. Sterilized women tend to be less educated even within caste and religious subgroups. In the subsamples of Hindu and Muslim women, sterilized women are also wealthier. The correlation between sterilization and wealth is however negative for Sikh women, not very significant for Christian women and non-significant for Buddhist women.

The husband's education, which was not significant previously (Table 4, column (6)), matters within caste subgroups (Table A2, columns (1)–(4)). After controlling for the woman's education, scheduled castes were found to be less likely to be sterilized than others (Table 4, column (5) and (6)). When running separate regressions by religion, the picture changes slightly. Among Buddhist, Sikh and Muslim women, scheduled castes are more likely to get sterilized.

3.5 Self-assessed side effects

Twelve percent of women using contraceptives report experiencing problems due to their contraception. Table 5 displays, by contraceptive, the percentage of women reporting side effects. This percentage varies across contraception methods, and is the highest for sterilization. Seventeen percent of the sterilized women say they have faced health problems due to sterilization. These women are further asked about the nature of the health problems encountered. For each issue in a list of 11, women have to state whether it is one of the problems they have faced because of their current contraceptive method. This subjective assessment provides a first insight to the likely consequences of sterilization for health.

We explore whether sterilized women are more or less likely to mention the various issues, controlling for village fixed effects and for the same socio-economic characteristics as before. Table A4, in the Appendix, shows that, compared to women using IUD or pills, sterilized women are more likely to have felt unable to work (+4.6 percentage points), to have suffered from weakness (+13.2 points), bodyache or backache (+5.2 points), cramps (+1.1 points) and white discharge (+2.6 points).

However, it is extremely risky to assess side effects of a method, simply on self-

Table 5: Problems faced by women using a contraceptive method

Method	(1) Percentage by current method	(2) Percentage mentioning problems with current method
Female sterilization	62.19	17
Vasectomy	1.64	10
No-scalpel vasectomy	0.18	11
IUD/copper-T/loop	4.36	11
Oral pills	7.56	12
Condom/Nirodh	9.96	2
Rhythm/periodic abstinence	8.00	0
Withdrawal	4.69	0
Other modern method	0.39	1
Other trad. method	1.03	1
Observations	255 180	255 180

Sample: women using a contraceptive method and have given birth in DLHS 2. Source: authors.

assessment. First, women who are more conscious of their health are more likely to report side effects. Second, some side effects might be more difficult to attribute to the contraceptive method. For these reasons, we will now turn to the symptoms that are declared by women, independently of any reference to contraceptive methods. This being said, such descriptive evidence provides elements to suggest that sterilization, more than other modern methods, is likely to lead to health deficits.

3.6 Alternatives to sterilization

Before exploring the health issues affecting sterilized women, we describe the comparison group. Table 6 reports what the couples do when the woman is not sterilized, for the sample of interest, namely the sample of women who have already given birth.

Table 6: Alternatives to sterilization

Use of contraception in couples where the woman is not sterilized	Percentage among women who have given birth and are not sterilized
No contraception - non-pregnant women	56.51
No contraception - pregnant women	10.45
Traditional method (rhythm, periodic abstinence, withdrawal)	11.90
Condom/Nirodh	8.71
Oral pills	6.61
IUD/copper-T/loop	3.81
Male sterilization	1.60
Other modern method	0.34
Total	100
Observations	291 970

Sample: women who are not sterilized and have given birth in DLHS 2. Source: authors.

Women who are not sterilized do not, in majority, use any other contraceptive method at the time of the survey. Sixty-seven percent of the couples do not use any contraception (10.5% of the comparison group is constituted of pregnant women, who therefore have no reason to use a contraceptive at the time of the survey). Twelve percent of the couples rely on traditional methods, mostly periodic abstinence or withdrawal. The rest (21%) use a modern contraceptive method, and this method is predominantly condoms, followed by oral pills.

When we estimate the effect of sterilization, we will therefore compare women who got sterilized to women who did not, and use this "bundle" of alternatives. It is important to recall that the effect of sterilization is estimated by comparing sterilized women with women who are mostly not using any other modern contraceptives. In addition, for many existing studies taking place in developed countries, knowing the past use of contraceptives by women is important, as it might influence menstrual symptoms as well (see Gentile et al., 1998). In our case, it is of minor importance, as other contraceptives are barely used in India. Even if all women using IUDs or oral pills at one point in time end up sterilized, they will constitute a small minority of all sterilized women.

4 Empirical strategy

4.1 Model

We now discuss the identification of the effect of sterilization. Getting sterilized is a decision very often jointly made by the woman, her husband, and oftentimes her mother-in-law. This decision reflects preferences over family size, willingness to invest in different types of human capital, availability of different contraceptives, availability of health care more generally, as well as the potential pressure exerted by the health care system. The previous section has described the characteristics of adopters, but no clear-cut picture emerges from the description. The fact that simultaneously wealthier women but also less educated women tend to adopt sterilization suggests that the selection cannot be categorized as positive or negative. As a result, it is difficult to predict the sign of the bias when neglecting the omitted variable bias.

Second, analyzing the effect of sterilization on health outcomes faces the issue of reverse causality. Women who have serious health issues may be more prone to get sterilized if they fear that another pregnancy could be fatal to them; or, to the contrary, only healthy women might decide to take up sterilization if the surgery is perceived as detrimental to health.

Because of selection and reverse causality, the endogeneity of the sterilization choice has to be taken into account. We do so by: controlling for observed characteristics of the household and the woman, controlling for unobserved characteristics of the village (by running village fixed effects regressions) and by implementing an instrumentation strategy we describe below. In order to control for village fixed effects, we implement a linear probability model:

$$Y_{iv} = \alpha_0 + \theta Ster_{iv} + \mathbf{X}_{iv}\Lambda_0 + \delta_{0v} + \epsilon_{iv} \quad (1)$$

Y_{iv} is an outcome variable related to the health of woman i living in village v, $Ster_{iv}$ is a dummy equal to 1 if the woman has been sterilized, $\mathbf{X}_{iv}$ is a vector of household characteristics and δ_{0v} are village fixed effects. Controls include age, education, duration of the marriage, husband's age, husband's education, religion, caste and wealth. We now turn to the presentation of the identification strategy.

4.2 Preference for boys

The preference for boys in India is widespread and does not need to be demonstrated anymore. As shown by Bhalotra and Cochrane (2010), households target a given number of boys.[17] As a result, the desired family size changes when the sex-composition of the first-borns become known to the parents. Parents who get boys first end up with fewer children than those who get female children first. In particular, the gender of the first-born affects the desired family size. We focus on the first-born for two reasons. First, all households, even the more modern, wish to have at least one child. We can thus consider the fact of having a first child as an event that is beyond the parents' choice. Second, and more importantly, Indian households are also known for selecting children on their gender basis. However, Bhalotra and Cochrane (2010) have shown that the sex-ratio at birth of the first-born is within the "natural" range: it seems that parents do not sex-select for the first pregnancy (Figure 3 shows that the introduction of ultrasound sex-detection devices deteriorated the sex ratio for second births, not for first births).

The gender of the first-born is therefore an "external" event,[18] that is not driven by parents' preferences. This does not guarantee however its exogeneity with regard to maternal health. If women are better treated when they give birth to a son, then the gender of the first-born affects both sterilization decisions and the woman's health. In particular, Milazzo (2014) shows that women who have a male first-born are less likely to suffer from anemia and less likely to die at young ages than the ones who have a female first-born.[19]

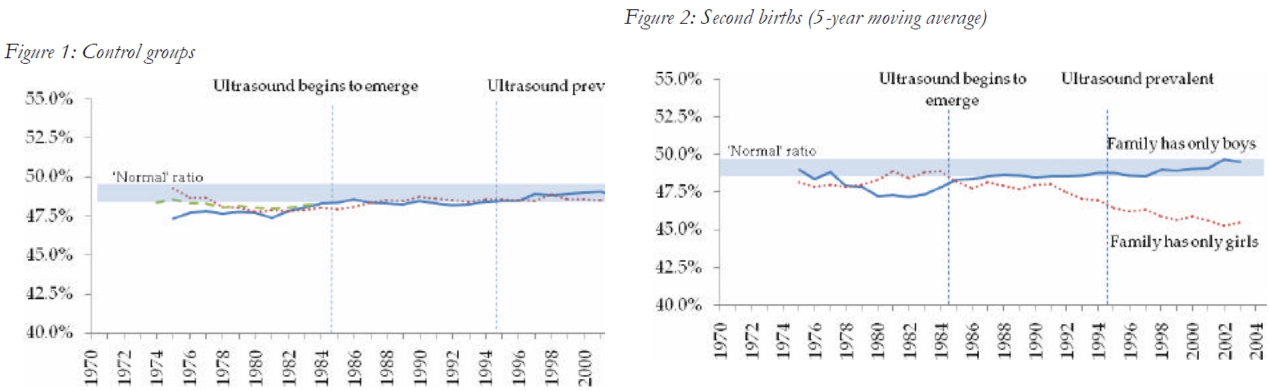
[17] Bhalotra and Cochrane (2010) find that the average household wishes to have two boys.

[18] The terminology employed here refers to the one offered by Deaton (2010).

[19] In the paper, she links anemia and death events to reduced birth-spacing and increased number of

Figure 3: Sex ratio at birth by parity

(a) Sex ratio for first births (b) Sex ratio for second births



Source: Bhalotra and Cochrane (2010).

4.3 Infant mortality

We also exploit the fact that women facing a higher risk of infant mortality should be more reluctant to adopt a permanent contraceptive. This has been documented in anthropological works (Patel, 1994). However, infant mortality is unlikely to satisfy exclusion restrictions: areas with higher infant mortality are presumably also the ones where health care is of poorer quality and women could also suffer from such poor quality. We will therefore focus on malaria prevalence, which is one specific driver of infant mortality. If malaria prevalence is affected by health policies implemented to fight against it (provision of bednets, parasite diagnostic kits and improved antimalarial medicines, interventions reducing reservoirs/waterholes and improving vector control, etc.), it also has a strong exogenous component: climate. Indeed, the size of the mosquito population as well as the ability of the malarial parasite to develop depend on temperature, rainfall and land-surface heterogeneity (see subsection A.4 of the Appendix for details). The malaria incidence predicted by the climate–disease model of Lauderdale et al. (2014) captures only the exogenous component of malaria prevalence. However, because malaria, even based on climate factors, should affect population health, we do not assume its exclusion from the main regression.

The Lauderdale et al. (2014) model uses the most reliable existing sources on rainfall and temperature.[20] Figure 4a displays the annual incidence of malaria as simulated by

pregnancies. It could also be associated with sterilization decisions.

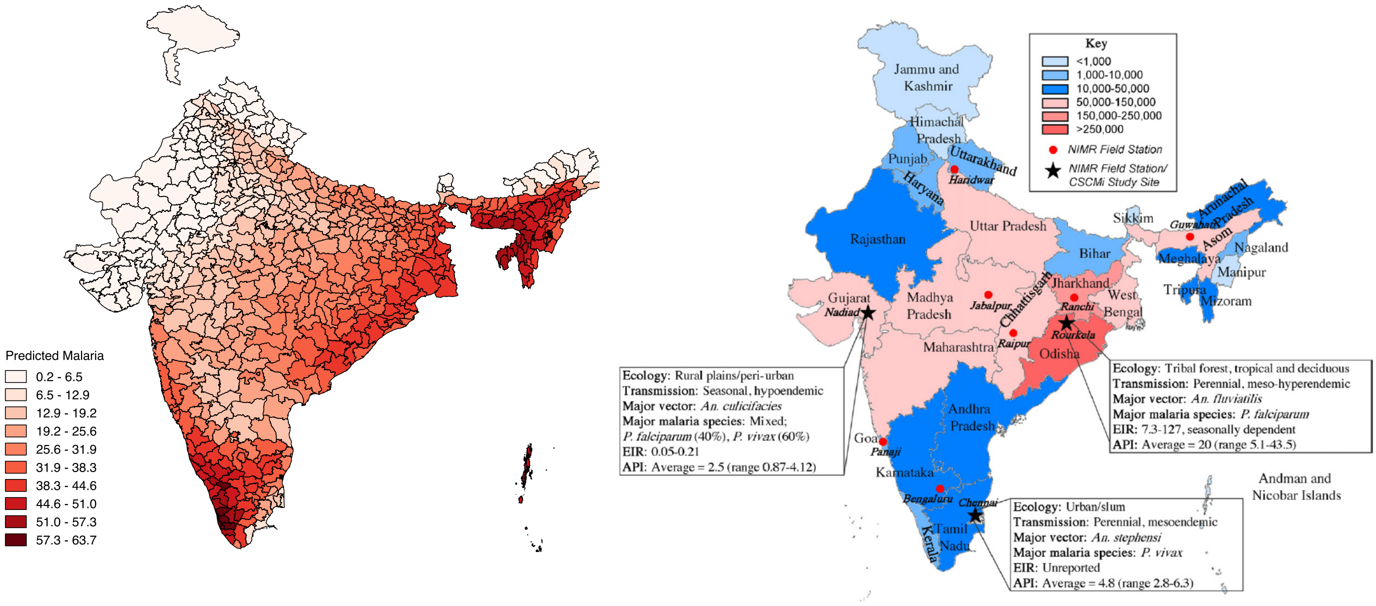
[20]Rainfalls are provided by the Tropical Rainfall Measuring Mission (TRMM), which has a fine grid of $0.25° \times 0.25°$, while temperatures are obtained from the Interim ECMWF Reanalysis (ERAI). TRMM has been shown to be a very reliable measure of rainfalls for tropical regions and in particular for India; it combines various satellite measures with local ground rain-gauges. Where rain-gauges are missing, the interpolation relies on a calibrated measure of the relation between cloud temperature and *in situ*

Lauderdale et al. (2014) for the period 1998–2010. Figure 4b shows the malaria endemicity as measured by the National Vector Borne Disease Control Programme for the year 2010 and mapped by Das et al. (2012). We observe similarities between the two maps, which is expected, but we also find that in some areas (the southern states, for instance) they differ markedly. This likely comes from the fact that these states are wealthier and therefore more equipped for fighting the disease.

Figure 4: Malaria

(a) Climate-driven malaria, as predicted by the Lauderdale et al. model

(b) Actual malaria. Source : Das et al. (2012)



As said, we simply use the modeled malaria based on climate for the period 1998–2010. We do not use temporal variation in rainfall and temperature because we consider that women, when taking their sterilization decisions, appreciate the risk of infant mortality through interactions in their network (close family, neighbors). Relatively rare events such as child death might be transmitted over years or maybe generations. Patel (1994) documents that mothers-in-law advocate strongly against sterilization if they have themselves witnessed such an event.

Last, the information obtained from the model is provided in grids, but we simply aggregate the information at the district level, to be matched with our datasets. We can also match the information at a lower administrative level (called block/taluk/tehsil), but this does not change the results (neither in terms of point estimates nor in precision).

observed rain (and not on a linear interpolation, which is often a flaw of gridded data). ERAI has a spatial resolution of 1.5°× 1.5°.

4.4 Preference for boys and infant mortality

Because households wish to ensure a male offspring, they are not only postponing sterilization when the first-born child is a girl, they should also postpone sterilization when they have a male first-born but face a high risk of infant mortality. To put it differently, for a given risk of infant mortality, they should postpone sterilization more if their first-born is a boy. If this is indeed the case, we can use the interaction between gender of the first-born and climate-driven malaria as an instrument for sterilization. Rather than controlling for malaria, we keep controlling for village fixed effects, which provides a stronger identification. Namely, the identification will rely on the fact that two women, who have a male first-born and live in villages with different infant mortality, will adjust the decision and timing of sterilization to these differences in infant mortality. To put it differently, in a given village, a woman who has a male first-born will reduce more her willingness to undergo the sterilization compared to the women who has a girl first-born if the village is at high risk of infant mortality. The model is estimated in 2SLS:

$$Y_{iv} = \alpha_0 + \theta Ster_{iv} + \beta_0 Male_{iv} + \mathbf{X}_{iv}\Lambda_0 + \delta_{0v} + \epsilon_{iv} \quad (2)$$

$$Ster_{iv} = \alpha_1 + \beta_1 Male_{iv} + \gamma_1 Male_{iv} \cdot Malaria_v + \mathbf{X}_{iv}\Lambda_1 + \delta_{1v} + \eta_{iv} \quad (3)$$

where $Male_{iv}$ is a dummy variable for the first-born's gender and $Malaria_v$ is the climate-driven malaria in the village.

4.5 Interpretation of the estimates

It is interesting to clarify what kind of effects are taken into account with our estimations. For doing so, we start by listing the changes associated to sterilization in an OLS/control framework and then discuss which mechanisms are still present when one estimates the effect of sterilization with the specified instrument. Women who are sterilized: a) might suffer from the surgery, b) avoid additional pregnancies and births, which could have direct and indirect effects on their health, c) avoid the use of other contraceptives, which could induce side effects, d) may intrinsically differ from the others (preferences with regards to fertility, bargaining power within the couple, etc.) and e) should have already reached their desired fertility level, which led most of them to take this decision. It is important to recognize that d) and e) prevent us from inferring a causality based on the OLS. Table A1, in the Appendix, provides the average number of children, by age and sterilization status. From this table, we see that younger women who are sterilized already have a large number of children, more than non-sterilized women. This comes from mechanisms d) and e). However, from age 33, the trend reverses and women who are sterilized are the ones who manage to keep their fertility low (b). As already mentioned, Bharadwaj (2015) finds that sterilization reduces the number of living children by 0.81.

Our instrument plays on the fact that women who have a male first-born reach their desired fertility level faster than the others (and that is particularly so when malaria is low). In order to simplify our point here, let us imagine that women decide to sterilize only when they get a male offspring.[21] Simplify even further by assuming that there is an equivalence between getting a male child and getting sterilized. Then, right after the first birth, women getting a male offspring get sterilized, others do not. At this moment, women who are sterilized have the same number of children as the others. So the main effect of the sterilization is due to the surgery and its potential complications (mechanism (a). Two to three years after however, non-sterilized women have either increased their number of pregnancies (mechanism b) or taken other contraceptives (c). As time passes, more and more pregnancies may take place and the 2SLS estimate is an average of effects of sterilization for different durations since sterilization. The instrumentation strategy therefore eliminates the omitted variable bias present in (d) and (e).

Obviously, it would be of interest to assess the consequences of sterilization in the light of the effect of other types of contraceptives. This would entail identifying separately the mechanism (a). However, in our case, we do not have an exogenous variation for other contraceptives take-up and therefore can only assess the global effect of sterilization.

Last, there might be some selection issues plaguing our estimates. Selection occurs for two reasons: first, observed sterilized women are the ones who survived the surgery, but we expect this selection to be minor because the number of deaths associated with sterilization seems to be low (603 identified cases in four years between 2009 and 2012). Even though this is likely a conservative estimate of deaths due to sterilization, it has to be compared to a rough estimate of three million tubectomies performed each year[22]). The risk of death in a sterilization procedure seems therefore of the order of magnitude of 0.004 percentage points. Second, sterilized women have fewer pregnancies and deliveries and therefore a lower risk to die at delivery or because of complications. The maternal mortality ratio in India was estimated at 414 (for 100 000 live births) in 1998 and 298 in 2004.[23] If sterilization leads to -0.81 children, then it reduces the risk of dying by 0.24 percentage points to 0.33 percentage points. In both instances, biases associated with attrition are likely extremely small.

[21]The differentiation between areas of various malaria prevalence simply allows us not to assume that having a male first-born does not affect how women are treated.

[22]Authors' computations based on figures provided by the Ministry of Health and Family Welfare, acquired through the Health Information System and `http://164.100.47.132/Annexture_New/lsq15/11/au4404.htm`.

[23]WHO, UNICEF, UNFPA, World Bank Group, and the United Nations Population Division. Estimates obtained from the World Bank website.

5 Results

5.1 Control strategy

We start by describing how sterilization correlates with the health variables. The dependent variables are the full list of health questions included in the surveys. These symptoms are vaginal discharge, irritation, ulcers around the vulva, pain in the abdomen, swelling in the groin, backache, pain and spotting during sexual intercourse, menstruation problems, fever, mass coming out of the vagina, involuntary escape of urine while sneezing or coughing, and lump in the breast (DLHS 2).[24] All these health issues can be symptoms of reproductive tract infections or sexually transmitted infections. The prevalence of these health problems in the population varies. The most frequent symptoms are low backache (20% of the women who have already given birth), vaginal discharge (16%), menstruation problems (12%) and pain in the abdomen (10%). Then, most of the other health problems (irritation, pain while urinating, fever, pain during sexual intercourse, mass out of the vagina and involuntary escape of urine) are reported by 4 to 7% of the women who have already given birth. The other symptoms are quite rare, with less than 2% of women reporting them (ulcers, swelling in the groin, lump in the breast, spotting during sexual intercourse).

Regarding anthropometric measurements collected in DHS 2, the average levels are fairly low, as expected for the Indian population. In particular, 31.5% of the female population is underweight (BMI < 18.5) and 51% is anemic (hemoglobin level < 12g/dL).

Table 7 shows that women who have been sterilized are more likely to suffer from any of the health problems mentioned than non-sterilized women. Coefficients are significant at the 1% level for all health issues. The magnitude of these associations is sizable. The last line of each panel of Table 7 reports the mean of the dependent variable in the sample. Sterilization is associated with an increase by 15–20% of most symptoms with respect to their mean. For instance, while 16% of women suffer from vaginal discharge, being sterilized is associated with an increase in the likelihood of suffering from vaginal discharge by 3 percentage points. The highest association is found for menstruation problems. While 12.5% of women having given birth suffer from menstruation problems, being sterilized is associated with an increase in the prevalence of menstrual issues by 5.7 percentage points, which is an increase by 46% of the prevalence.

For women who experienced menstruation problems, additional questions are asked in order to investigate the nature of these problems. Table A5, in the Appendix, presents the results. Sterilization is associated with increased likelihood of painful periods, altered length, timing, and amount of bleeding. Effects associated with sterilization are large.

[24] These are separate questions for each symptom.

Table 7: Consequences of sterilization - OLS

Panel A							
	(1) Vaginal discharge	(2) Itching or irritation	(3) Boils/ulcers around vulva	(4) Pain in abdomen	(5) Pain when urinating	(6) Swelling in groin	(7) Low backache
Woman has been sterilized	0.034***	0.009***	0.003***	0.022***	0.010***	0.004***	0.044***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	440 377	440 337	440 326	440 336	440 336	440 317	440 335
Mean Y	0.163	0.0716	0.0282	0.102	0.0635	0.0273	0.202
Panel B							
	(1) Pain during sex. interc.	(2) Spotting aft. sex.	(3) Menstrual problems	(4) Fever	(5) Mass out of vagina	(6) Escape of urine	(7) Lump in the breast
Woman has been sterilized	0.009***	0.001***	0.056***	0.009***	0.009***	0.006***	0.003***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	440 310	440 323	440 626	440 331	440 329	440 318	440 265
Mean Y	0.0446	0.00948	0.123	0.0583	0.0459	0.0428	0.0120

Sample: women having given birth in DLHS 2. Standard errors clustered at the village level in parentheses. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth and village fixed-effects. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: authors.

The increase (in percentage points) of the likelihood of experiencing painful or excessive bleeding amounts to 60–70% of the sample mean.

Table 8 provides results on the anthropometric and biological measurements from the DHS. As expected, sterilization is not associated with any change in height. However, it is associated with a moderate increase in weight and hence BMI, as well as a non-negligible improvement in the hemoglobin level. Sterilization could therefore be associated with health improvements, but in other dimensions than the already scrutinized symptoms. However, before concluding to positive "effects," it is important to analyze in greater detail this result. First, we see that the increase in BMI does not lead to a reduction in the share of underweight women. This is most likely due to the fact that it shifts upwards the upper-part of the distribution in BMI, rather than the lower part. The health improvement in that regard seems somewhat limited. By comparison, the improvement in hemoglobin level leads to a reduction in the share of anemic women. This seems at odds with the previous result that sterilized women are more prone to menstruation issues, which could be a mechanism of *increased* anemia. However, being sterilized also reduces the number of pregnancies and, as such, could reduce anemia. In order to check whether this explanation holds, we compare the BMI and hemoglobin level of pregnant and breastfeeding women (among those who are not sterilized). We do so in a similar regression framework as the one developed so far. Controlling for socio-economic background and village fixed effects, we find that pregnant women have a lower hemoglobin level (-0.72). Breastfeeding women also have a lower hemoglobin level compared to non-pregnant and non-lactating women (-0.18).[25] The reduction in the number of anemic women could therefore come from the avoidance of pregnancies. By comparison, the result is not so easily explained for BMI since non-sterilized women incur large variations in their weight when they give birth (increases during pregnancy (+1), followed by decreases when breastfeeding (-0.32)). We postpone further possible explanations for changes in BMI.

Table 8: Consequences of sterilization - OLS

	(1) Height	(2) Weight	(3) BMI	(4) Hemoglobin	(5) Underweight	(6) Anemia
Women has been sterilized	0.051	0.159**	0.071**	0.268***	0.001	-0.053***
	(0.048)	(0.074)	(0.031)	(0.015)	(0.004)	(0.004)
Observations	74 554	74 525	74 399	71 752	74 399	71 752
Mean Y	151.6	47.62	20.67	11.73	0.315	0.510

Sample: women having given birth in DHS 2. Standard errors clustered at the village level in parentheses. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth and village fixed-effects. *** p <0.01, ** p <0.05, * p <0.1. Source: authors.

5.2 Heterogeneity of the "effect"

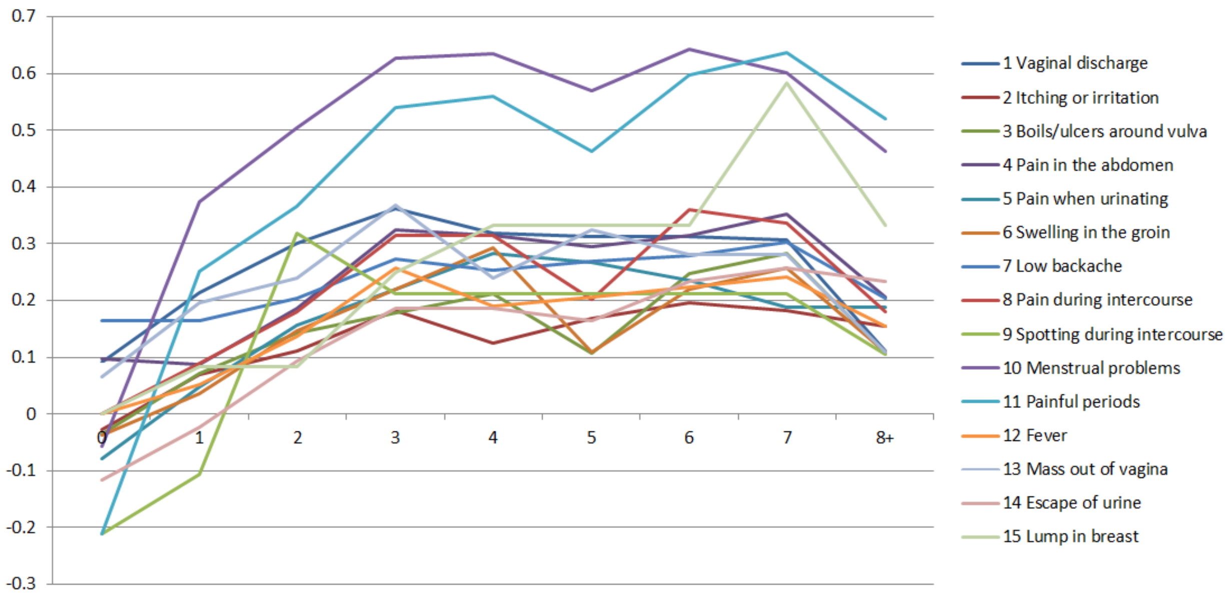
We now explore the heterogeneity of the association between sterilization and health outcomes. We are first interested in whether the associations we observe are mostly transitory or remain over time. In particular, since women self-assess their own health status, it could be that they associate a recent sterilization with poorer health, attributing by mistake adverse symptoms to the surgery. We simply exploit the fact that we observe women who have undergone the surgery more or less recently. More precisely, for women who got sterilized, we know the number of years that have passed. It is censored at eight years or more (in DLHS 2). Conditional on age, we compare women who got sterilized, say, one year before the survey to women who got sterilized, say, five years before the survey. The estimated regression is the following one:

$$Y_{iv} = \alpha_0 + \sum_{n=0}^{n=8} \theta_n Ster_{iv} \cdot (1 + (Years\_Ster_{iv} = n)) + \mathbf{X}_{iv}\Lambda_0 + \delta_{0v} + \epsilon_{iv} \quad (4)$$

[25] Regressions not reported but available from the authors. All reported coefficients are significant at the 1% level.

where $Years\_Ster_{iv}$ is the years since sterilization for woman i in village v. For each health outcome, we estimate nine parameters. The interacted variables take on ten different values: 0 when non-sterilized, 1 if sterilized in the survey year, 2 if sterilized in the previous year, etc. The reference modality is being non-sterilized, while θ_0 provides the association of having been sterilized in the year of the survey (compared to not being sterilized) with the health outcome, θ_1 the association between a sterilization in the year before and the health outcome, etc.

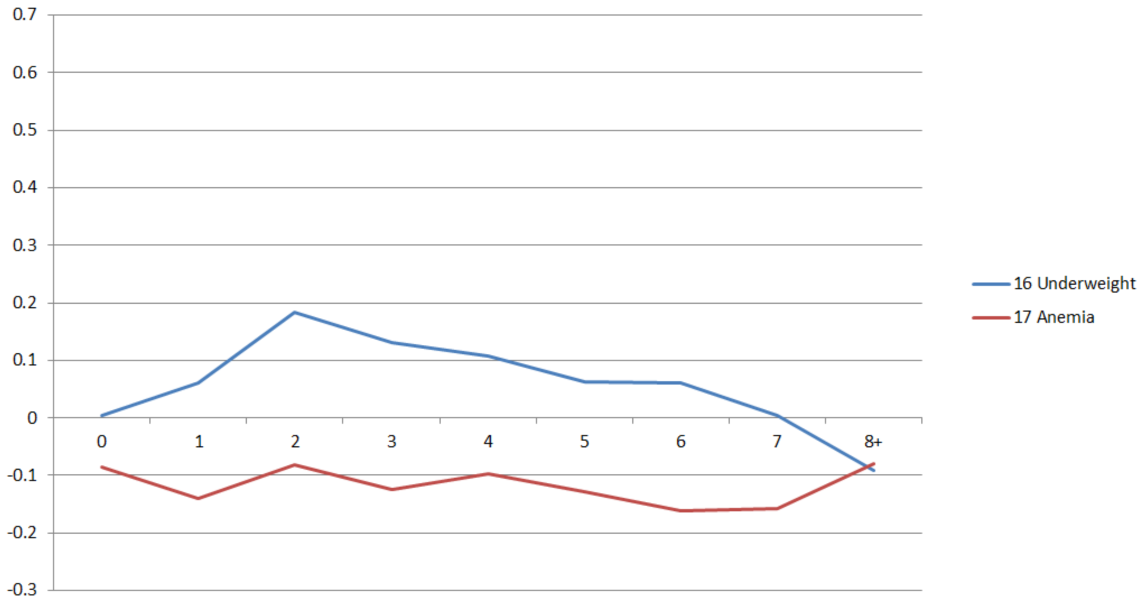
Figure 5: Effect of sterilization, by years since sterilization (DLHS 2)



Note: the graph provides the estimates obtained from regressions (4), scaled by the mean of the dependent variable. Interpretation of the first point of the blue-violet line (10: Menstrual problems): A sterilization done in the year is associated with a reduction by 6% of the likelihood to suffer from menstrual problems, compared to not being sterilized. Second point of the same line: a sterilization done in the year before is associated with an increase by 37% of the likelihood to suffer from menstrual problems, compared to not being sterilized. Sample: women who have given birth in DLHS 2. Source: authors.

In Figure 5 we plot each of these estimated coefficients scaled by the mean of the dependent variable in the sample. The new coefficients are to be interpreted as the increase in percentage of the prevalence. Reported standard errors are not provided for the sake of clarity, but most coefficients are significantly different from 0 at the 1% level as in the results in the previous section. Figure 5 shows that the associations tend to increase in the first three years after sterilization and then remain steady. We observe a slight decline for women who got sterilized more than eight years ago. This could be due to endogenous attrition (the category 8+ includes women who were sterilized a long time ago and only healthier women survive). Even if sterilization is not a pure random event, this result is important. First, women of the same age who got sterilized one or

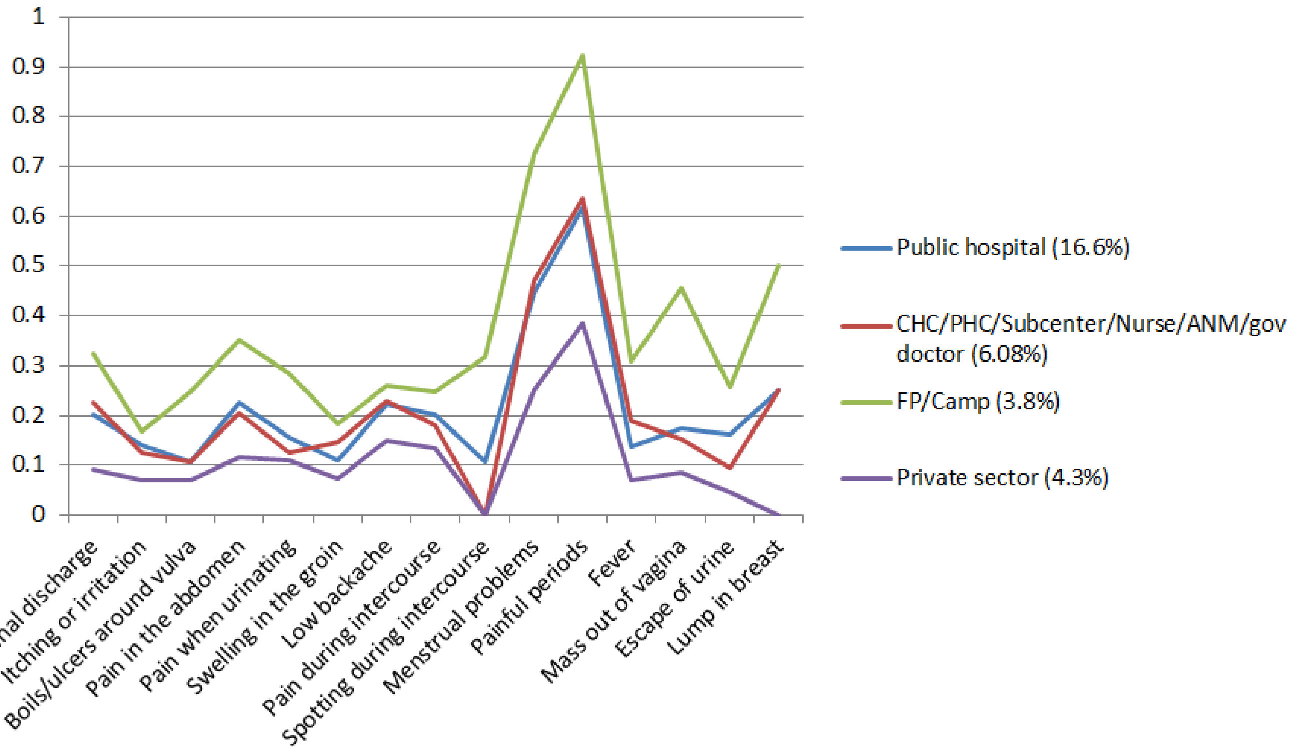
Figure 6: Effect of sterilization, by years since sterilization (DHS 2)



Note: the graph provides the estimates obtained from regressions (4), scaled by the mean of the dependent variable. Interpretation of the first point of the red line (17: Anemia): A sterilization done in the year is associated with a reduction by 9% of the likelihood to suffer from anemia, compared to not being sterilized. Second point of the same line: a sterilization done in the year before is associated with a decrease by 13% of the likelihood to suffer from anemia, compared to not being sterilized. Sample: women who have given birth in DHS 2. Source: authors.

two years apart are presumably not very different from each other, so the bias in the coefficient should be similar. It therefore makes sense to compare the coefficients and to conclude that the adverse effects of sterilization display fully only after three years. Second, this result invalidates the hypothesis that most of the obtained associations arise from a biased assessment by the women. One concern raised above was that women could be more likely to report symptoms in the reproductive sphere because they have been more in contact with medical staff or have thought more about their reproductive health. For instance, if the process leading to sterilization increases the awareness regarding gynecological health, women would put more emphasis on gynecological symptoms. If this was the case, the association should be stronger right after the operation, not three years later. We therefore conclude that self-declared symptoms do not reflect a salient memory of the operation or an increased knowledge gained throughout the process. Our results are not likely to suffer from an assessment bias.

Figure 7: Effect of sterilization, by facility



Note: the graph provides the estimates obtained from regressions (5), scaled by the mean of the dependent variable. Interpretation of the first point of the green line: A sterilization performed in a camp is associated with an increase by 32% of the likelihood to suffer from vaginal discharge, compared to not being sterilized. Sample: women who have given birth in DLHS 2. Source: authors.

We run the same analysis for the underweight and anemia variables. We find a very steady "reduction" of anemia associated with sterilization, that suggests that the improvement is durable. By comparison, sterilization is associated with an *increase* in the likelihood of being underweight two years after the surgery, which lasts for three years.[26] The positive association between sterilization and reduction in underweight likelihood is only visible for women who were sterilized a long time ago (more than eight years). One tentative explanation could be that some women who were sterilized a long time ago decide to undergo a hysterectomy to reduce the menstruation issues. The hysterectomy might then lead to hormonal disorders and weight gain. In any case, the results on BMI should be viewed with extreme caution, precisely because of the observed variation in this variable when the woman falls pregnant.

We now quickly describe how the association between sterilization and health outcomes varies with the facility where the sterilization was performed. The regression is the following one:

$$Y_{iv} = \alpha_0 + \sum_{k=0}^{k=3} \theta_k Ster_{iv} \cdot (1 + (Facility\_Ster_{iv} = k)) + \mathbf{X}_{iv}\Lambda_0 + \delta_{0v} + \epsilon_{iv} \tag{5}$$

where $Facility\_Ster_{iv}$ is the facility of sterilization and can take four different values: public hospital, a broad category encompassing the local public sector (community health center, primary health center, subcenter, and any declaration that suggests that the sterilization actually took place in one of these facilities[27]), a sterilization camp and the private sector. Again, the reference modality is constituted of women who did not get sterilized and the effects are scaled by mean prevalence in the population. Here, however, we cannot interpret the differences between associations as causal, since the facility in which women get sterilized reflects their own choice and pressure from the health sector. Poorer women are more likely to be sterilized in camps, where care is presumably of lower quality. Figure 7 confirms that women who were sterilized in camps have the highest adverse "effects" for each type of symptom. We identify significant negative associations even with sterilizations performed in the private sector, despite the presumably better care that is offered to women. Unfortunately, the DHS data do not provide the place of sterilization and we are unable to run the same analysis for anthropometric and biological measurements.

5.3 2SLS

We first check that the interaction between the gender of the first-born and climate-driven malaria predicts female sterilization, conditional on village fixed effects and household and

[26] θ_2, θ_3 and θ_4 are significantly different from 0, as well as θ_8.

[27] In particular, we include in this category responses such as: nurse, ANM and government doctor, who are not supposed to perform outside of the previously mentioned structures but could have been named by respondents to refer to the centers.

women's characteristics. Table 9 shows this is the case and the associated F-stats are high. The interpretation of the effect is the following. Women having a male first-born are +9.8 percentage points more likely to get sterilized but the effect is lower when the area is characterized by a high prevalence of (climate-driven) malaria. Essentially, the effect vanishes when the variable for malaria is equal to 0.098/0.0015=65.3. The malaria variable actually ranges from 0.18 to 63.7, which means that the male first-born effect is equal to 0 only when the malaria is at its maximum. The advantage of having a male first-born for a family is not considered as certain if the malaria is too prevalent in the area. It is interesting to note that we control for village fixed effects throughout the analysis. As a result, the effect of malaria is only identified via different decisions made by households in the same village, depending on whether they had a male or a female first-born. The effect of having a male first-born on sterilization and its heterogeneity with respect to malaria is strikingly the same when we use the DHS sample. The F-stat is smaller due to a lower number of observations, but still higher than conventional levels of acceptance. Given that our instrument is based on a district-level predicted malaria, we allow for some correlation between error terms at the district level in the 2SLS estimations.

Table 9: Prediction of sterilization - first stage

	Woman has been sterilized		
	DLHS 2	DLHS 2	DHS 2
	(1)	(2)	(3)
Male first born	0.099***	0.098***	0.089***
	(0.004)	(0.004)	(0.008)
Male first born × Malaria (d)	-0.0015***	-0.0015***	-0.0012***
	(0.0001)	(0.0001)	(0.0002)
Observations	430 129	430 129	77 266
Adjusted R2	0.149	0.148	0.102
District FE	Yes	No	No
Village FE	No	Yes	Yes
F-stat	158.7	156.6	38.68

Sample: women having given birth in DLHS 2 (col. 1 and 2) and in DHS 2 (col. 3). Standard errors clustered at the district level in parentheses. The provided F-stat is the value of the Fisher on the test that the coefficient for male first born × Malaria (d) equals 0. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth and fixed effects. (d) means that the malaria variable is defined at the district level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: authors.

We now turn to the results offered by the 2SLS. Table 10 shows that only some of the previously significant effects persist with the instrumentation. We find that sterilization increases the likelihood of suffering from low backache (+10 points), from pain during sexual intercourse (+5 points), from spotting after sexual intercourse (+2.9 points) and from menstrual issues (+11.2 points) (more precisely, from excessive periods, see Table A6). The effects that are not significant anymore have in general strongly decreased compared to the OLS: their non-significance is not simply due to a lower precision. By comparison, the significant 2SLS estimates are stronger than their OLS counterparts. As a result, our strategy seems to be able to disentangle causality from correlation. In particular, it is reassuring to observe that the significant effects match the stated side-effects of sterilization (in the survey and in qualitative interviews with sterilized women).

Table 10: Consequences of sterilization - 2SLS

Panel A							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Vaginal discharge	Itching or irritation	Boils/ulcers around vulva	Pain in abdomen	Pain when urinating	Swelling in groin	Low backache
Woman has been sterilized	0.067	0.020	0.007	0.004	-0.004	0.001	0.098*
	(0.047)	(0.037)	(0.021)	(0.044)	(0.033)	(0.021)	(0.053)
Observations	429 197	429 178	429 161	429 172	429 166	429 147	429 170
Mean Y	0.166	0.0726	0.0286	0.103	0.0645	0.0276	0.205
Panel B							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Pain during sex. interc.	Spotting aft. sex.	Menstrual problems	Fever	Mass out of vagina	Escape of urine	Lump in the breast
Woman has been sterilized	0.048*	0.027**	0.117***	0.027	0.007	-0.028	0.016
	(0.027)	(0.014)	(0.043)	(0.032)	(0.032)	(0.026)	(0.014)
Observations	429 144	429 152	429 418	429 157	429 159	429 151	429 097
Mean Y	0.0450	0.00941	0.125	0.0583	0.0466	0.0434	0.0120

Sample: women having given birth in DLHS 2. Standard errors clustered at the district level in parentheses. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth, whether the first-born is a boy and village fixed effects. The probability of being sterilized is instrumented by the interaction between the predicted malaria at the district level and whether the first-born is a boy. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: authors.

Table 11 provides the results for the DHS sample. We find again that weight, BMI and hemoglobin levels are positively affected by sterilizations. It therefore seems that avoidance of pregnancies improves the nutritional status of women. However, these effects seem to be mostly driven by the upper part of the distribution, since the effects on the likelihood to be underweight or anemic are non-significant at the 10% level. We lack precision in these estimations and it is difficult to make a decisive point based on these estimates.

Again, the 2SLS estimates tend to be larger than the OLS. This would be consistent with positive selection into sterilization: women in better health are more likely to undergo the sterilization. In order to check this, we would need information on women's health before sterilization. The data are only cross-sectional and do not allow us to com-

Table 11: Consequences of sterilization - 2SLS

	(1) Height	(2) Weight	(3) BMI	(4) Hemoglobin	(5) Underweight	(6) Anemia
Women has been sterilized	1.346	7.583***	3.055***	1.634**	-0.183	-0.291
	(1.667)	(2.704)	(0.853)	(0.816)	(0.114)	(0.192)
Observations	71 954	71 926	71 802	69 214	71 802	69 214
Mean Y	151.6	47.54	20.66	11.73	0.317	0.511

Sample: women having given birth in DHS 2. Standard errors clustered at the district level in parentheses. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth and village fixed-effects. The probability of being sterilized is instrumented by the interaction between the predicted malaria at the district level and whether the first-born is a boy. *** p <0.01, ** p <0.05, * p <0.1. Source: authors.

pare each health outcome at different dates. However, health outcomes during the last pregnancy (so, obviously, before sterilization) are recorded. We use these variables as placebo variables: if sterilization is not driven by preferences with regards to health, then we would expect it to be uncorrelated with prior health conditions. To put it differently, running OLS regressions on the placebo variables will inform on the direction of the selection and running 2SLS regressions on the placebo variables evaluates the validity of the identification strategy.

5.4 Placebo

The placebo variables we use are the following. First, we use care during the last pregnancy, which is difficult to interpret, since one cannot ascertain whether care is consumed because it is of good quality or because it is needed. We also use records of symptoms during the last pregnancy (swelling, paleness, visual disturbances, excessive fatigue, etc.). We also check using information on the last labor (whether it was prolonged, obstructed, led to excessive bleeding, etc.) and, last, we have post-delivery complications.

The OLS estimation on the placebo confirms that women in better health are more likely to undergo the sterilization (Table A7, in the Appendix). In particular, we find that sterilization is associated with access to antenatal care but a lower number of examinations during the last pregnancy, but also to a lower prevalence of various symptoms during the last pregnancy. We find no evidence of a correlation between sterilization and post-delivery complications.

We now turn to the 2SLS on the placebo variables (Table 12). We find that our identification strategy is convincing at removing the endogeneity bias since we find virtually no effect of sterilization on the occurrence of previous health symptoms.

Table 12: Placebo - 2SLS

Panel A : Care during last pregnancy		
	(1)	(2)
	Antenatal care	Number of examinations
Woman has been sterilized	-0.059	-0.407
	(0.145)	(0.725)
Observations	187 448	187 408
Mean Y	0.656	2.559

Panel B: Health status during last pregnancy						
	(1)	(2)	(3)	(4)	(5)	(6)
	Swelling hands, feet, face	Paleness, giddiness	Visual disturbances	Excessive fatigue	Convulsions	Weak/no mov. of fetus
Woman has been sterilized	0.024	0.017	-0.117	-0.066	-0.081	-0.070
	(0.143)	(0.128)	(0.097)	(0.058)	(0.085)	(0.070)
Observations	197 383	197 383	197 383	197 383	197 383	197 383
Mean Y	0.190	0.116	0.0772	0.0193	0.0473	0.0267

Panel C: Events during last labor					
	(1)	(2)	(3)	(4)	(5)
	Premature labor	Excessive bleeding	Prolonged labor	Obstructed labor	Breech presentation
Women has been sterilized	0.008	0.077	-0.072	-0.014	-0.107*
	(0.111)	(0.095)	(0.120)	(0.103)	(0.061)
Observations	197 383	197 383	197 383	197 383	197 383
Mean Y	0.101	0.0611	0.142	0.180	0.0257

Panel D: Post-delivery complications						
	(1)	(2)	(3)	(4)	(5)	(6)
	High fever	Abdominal pain	Smelling vag. discharge	Excessive bleeding	Convulsion	Severe headache
Woman has been sterilized	0.106	-0.130	0.065	0.132	0.012	0.124
	(0.129)	(0.138)	(0.078)	(0.092)	(0.068)	(0.125)
Observations	197 383	197 383	197 383	197 383	197 383	197 383
Mean Y	0.134	0.178	0.0503	0.0623	0.0371	0.115

Sample: women having given birth in DLHS 2. Information about last pregnancies is recorded only if the last pregnancy took place less than three years before the survey. Standard errors clustered at the district level in parentheses. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth, gender of the first-born and village fixed effects. The probability of being sterilized is instrumented by the interaction between the predicted malaria at the district level and whether the first-born is a boy. *** p <0.01, ** p <0.05, * p <0.1. Source: authors.

6 Conclusion

This paper analyzes the impact of sterilization on health, and highlights that sterilizations have significant and strong adverse effects on the health of women. Using the sample of the 450 000 Indian women who have already given birth and are surveyed in the 2002–2004 wave of the District Level Household Survey, we show that sterilizations are more likely to be associated with a wide range of reproductive tract infections and gynecological symptoms. We find that adverse effects are stronger three years after the operation, and do not vanish over time. We show that adverse consequences are observed regardless of the medical facility in which the operation is performed. In addition, we show that sterilizations performed in camps and in mobile clinics are associated to stronger adverse effects (without being able to assess causality here). On the other hand, using the Demographic Health Survey collected in 1998–1999, we show that sterilization also improves women's health in another dimension: sterilized women put on weight and increase their hemoglobin levels, in a context where a large fraction of women are underweight and/or anemic. This is likely due to a lower number of pregnancies. However, we do not find that this reduces the prevalence of underweight and anemic women, and the positive effects seem therefore limited.

Our paper provides a decisive contribution to the literature, which has so far failed to establish that sterilizations result in painful or abnormal menstrual cycles, and does not provide any clear-cut evidence on the adverse health consequences of sterilizations. Gentile et al. (1998) stress that most of the studies concluding in favor of a post-tubal litigation syndrome do not control for potential confounding factors. We control for age of the woman and age of the couple, we take into account education, husband's education and wealth, and we capture norms and status through religion and caste variables. In addition, village fixed effects allow us to control for omitted variables common to all women living in the same village.

Contrary to the existing literature, we take into account the fact that sterilizations are undergone by women likely to be different from others. Regressions in a simple linear probability framework show that sterilized women are likely to enjoy better health. Failing to account for this element leads to underestimating the adverse effect of sterilization on women's health. This might actually explain why many existing studies do not attribute adverse health outcomes to sterilization. We deal with selection and reverse causality issues, and are thus able to estimate the consequences of sterilization on health. We do so by implementing an innovative instrumentation strategy. We rely on the fact that women who face a lower risk of child mortality and who have already had a boy are more likely than others to get sterilized. We instrument the probability of getting sterilized by the interaction between the gender of the first-born and an exogenous measure of child mortality, which is a predicted measure of malaria based on a weather–disease model.

We find that women who have been sterilized are 50% more likely to suffer from low backache, and 100% more likely to suffer from pain during sexual intercourse, from painful periods and excessive bleeding. Last, sterilization increases by 300% the probability to suffer from abnormal vaginal bleeding during sexual intercourse.

The effects associated with vaginal discharge and menstruations are in line with the medical literature, which has conjectured that the destruction of the fallopian tube might reduce the blood supply of the ovary, alter its function, and lead to a variety of menstrual disorders (see Gentile et al., 1998). Yet, as compared with the existing literature, our results go beyond, and highlight that sterilization has an impact not only on menstruation, but on a wide range of health problems.

Our results not only provide a unique glance at the situation experienced by nearly 182 million women in India.[28] They also contribute to learning about the experience of women across many developing countries. Sterilization is the main contraception method available in the Dominican Republic, Panama, Salvador, Guatemala, Colombia, Nepal, Brazil, Nicaragua and China. Our paper thus questions the way family planning policies and programs are designed in many developing countries.

[28]This figure is obtained by applying the sterilization prevalence observed in the DLHS 2 to the population of women as measured by the 2011 Census.

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A Appendix

A.1 Descriptive statistics

Table A1: Descriptive statistics - main variables

Variable	Women having given birth Mean (SD)	Diff	Sterilized women Mean (SD)
Woman has been sterilized	0.352		1
Age	30.881	***	33.785
	(7.08)		(6.05)
Education	4.276	***	3.756
	(4.91)		(4.47)
Hindu	0.768	***	0.834
Muslim	0.115	***	0.07
Christian	0.064	***	0.05
Sikh	0.025		0.025
Buddhist	0.014	***	0.012
Other religion	0.014	***	0.009
Scheduled caste	0.168	***	0.178
Scheduled tribe	0.155	***	0.122
Oth. backw. caste	0.376	***	0.407
Other caste/tribe	0.29	***	0.284
Caste unknown by respondent	0.011	***	0.009
Wealth	0.005	***	0.098
Husband edu.	6.782	***	6.44
	(5.21)		(4.98)
Age of couple	13.246	***	16.646
	(7.39)		(6.31)
Male first-born	0.523	***	0.566
Malaria (district)	24.077	***	23.903
Observations	450 663		158 881

$^{+}p < 0.1$, $^{\star}p < 0.05$, $^{\star\star}p < 0.01$, $^{\star\star\star}p < 0.001$ for diff. in means between sterilized and non-sterilized women. Source: authors.

Table A2: Probability of being sterilized - by caste

	(1)	(2)	(3)	(4)	(5)
	Dependent variable: woman has been sterilized				
	SC	ST	OBC	Other	Unknown
Age	0.002**	0.004***	0.000	-0.002***	-0.003
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Education	-0.007***	-0.003***	-0.006***	-0.007***	-0.009***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Husband edu.	-0.001**	0.002***	-0.001**	-0.004***	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age of couple	0.020***	0.017***	0.021***	0.023***	0.022***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Muslim	-0.047***	-0.006	-0.152***	-0.139***	-0.134***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Christian	-0.003	0.027**	-0.013	-0.027*	-0.020
	(0.02)	(0.01)	(0.01)	(0.01)	(0.05)
Sikh	-0.039**	0.008	-0.055***	-0.018*	-0.047
	(0.02)	(0.04)	(0.02)	(0.01)	(0.08)
Buddhist	-0.026*	-0.047**	-0.071**	-0.107***	0.041
	(0.02)	(0.02)	(0.04)	(0.03)	(0.12)
Other	0.023	0.009	-0.031	-0.015	-0.088
	(0.04)	(0.01)	(0.02)	(0.01)	(0.08)
Wealth	0.010***	0.012***	0.006***	0.002	0.019***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Observations	73 878	68 131	165 876	128 221	4 519
Village FE	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.146	0.129	0.145	0.156	0.142

Sample: women who have already given birth in DLHS 2. Reference category for religion: Hindu. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: authors.

Table A3: Probability of being sterilized - by religion

	(1)	(2)	(3)	(4)	(5)
	Dependent variable: woman has been sterilized				
	Hindu	Muslim	Christian	Sikh	Buddhist
Age	-0.000	0.000	0.003***	-0.002	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Education	-0.007***	-0.004***	-0.001	-0.008***	-0.002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Husband edu.	-0.000	-0.002***	0.002**	-0.008***	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age of couple	0.022***	0.014***	0.017***	0.025***	0.019***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Scheduled caste	-0.039***	0.031**	0.014	0.077***	0.093**
	(0.00)	(0.01)	(0.03)	(0.01)	(0.04)
Scheduled tribe	-0.061***	-0.020	0.019	0.027	0.063**
	(0.00)	(0.02)	(0.03)	(0.05)	(0.03)
Oth. backw. caste	-0.002	-0.004	0.034	0.024*	0.039
	(0.00)	(0.01)	(0.02)	(0.01)	(0.04)
Wealth	0.007***	0.005***	0.005*	-0.014***	0.008
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Observations	338 451	50 076	28 434	11 216	6 340
Village FE	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.148	0.0895	0.127	0.191	0.130

Sample: women who have already given birth in DLHS 2. Reference category for castes: higher castes. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: authors.

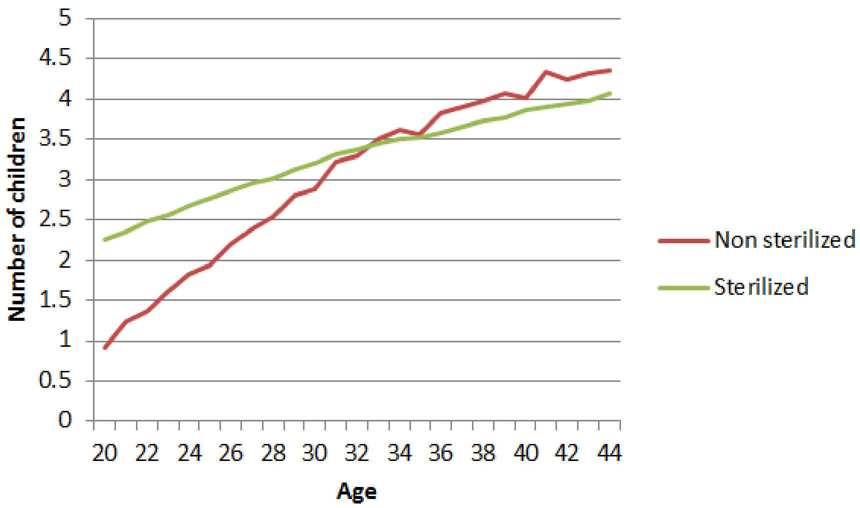
A.2 Subjective side effects of contraceptive methods

Table A4: Side effects of the current contraception method

Panel A	(1) Some problem	(2) Weakness/inabil. to work	(3) Bodyache/ backache	(4) Cramps	(5) Weight gain	(6) Dizziness
Reference category: Woman uses IUD/copper-T/loop or pills						
Woman has been sterilized	0.046***	0.032***	0.052***	0.011***	0.004***	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Uses a traditional method	-0.133***	-0.046***	-0.033***	-0.008***	-0.008***	-0.048***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Husband has been sterilized	-0.029***	0.006	-0.000	-0.001	-0.008***	-0.022***
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Couple uses condoms	-0.089***	-0.022***	-0.022***	-0.003***	-0.009***	-0.027***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Village FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	252 957	252 957	252 957	252 957	252 957	252 957
Mean Y	0.119	0.0522	0.0630	0.0137	0.00738	0.0273
Panel B	**(1) Nausea vomiting**	**(2) Breast tenderness**	**(3) Excessive bleeding**	**(4) Spotting**	**(5) White discharge**	**(6) Other problem**
Reference category: Woman uses IUD/copper-T/loop or pills						
Woman has been sterilized	-0.002***	0.001***	-0.002**	0.000	0.026***	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Uses a traditional method	-0.012***	-0.002***	-0.017***	-0.003***	-0.030***	-0.000***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Husband has been sterilized	-0.011***	-0.002***	-0.015***	-0.003***	0.006**	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Couple uses condoms	-0.009***	-0.002***	-0.017***	-0.003***	-0.013***	-0.000**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Village FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	252 957	252 957	252 957	252 957	252 957	252 957
Mean Y	0.00725	0.00313	0.0114	0.00319	0.0308	0.000399

Standard errors clustered at the village level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth. Source: authors.

Figure A1: Number of children, by age and sterilization status



Note: the curves indicate the average number of children of women of each age, separately by sterilization status. Sample: 20–44-year-old women in DLHS 2. Source: authors.

A.3 Results

Table A5: Consequences of sterilization - OLS - menstruation issues

	(1) Painful period	(2) Excessive bleeding	(3) Painful or excessive	(4) Prolonged bleeding	(5) Continuous bleeding	(6) Intermenstrual bleeding
Woman has been sterilized	0.032***	0.014***	0.040***	0.006***	0.002***	0.004***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	440 626	440 626	440 626	440 626	440 626	440 626
Mean Y	0.0508	0.0202	0.0632	0.00979	0.00476	0.00794

Sample: women having given birth in DLHS 2. Standard errors clustered at the village level in parentheses. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth and village fixed effects *** p <0.01, ** p <0.05, * p <0.1. Source: authors.

Table A6: Consequences of sterilization - 2SLS - menstruation issues

	(1) Painful period	(2) Excessive bleeding	(3) Painful or excessive	(4) Prolonged bleeding	(5) Continuous bleeding	(6) Intermenstrual bleeding
Woman has been sterilized	0.033	0.032*	0.060*	0.014	0.000	0.004
	(0.030)	(0.019)	(0.032)	(0.013)	(0.009)	(0.012)
Observations	429 418	429 418	429 418	429 418	429 418	429 418
Mean Y	0.0516	0.0205	0.0642	0.00993	0.00484	0.00810

Sample: women having given birth in DLHS 2. Standard errors clustered at the district level in parentheses. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth, whether the first-born is a boy and village fixed effects. The probability of being sterilized is instrumented by the interaction between the predicted malaria at the district level and whether the first-born is a boy. *** p <0.01, ** p <0.05, * p <0.1. Source: authors.

Table A7: Placebo - OLS

Panel A: Care during last pregnancy	(1) Antenatal care	(2) Number of examinations
Woman has been sterilized	0.011***	-0.111***
	(0.003)	(0.014)
Observations	191 159	191 119
Mean Y	0.659	2.593

Panel B: Health status during last pregnancy	(1) Swelling hands, feet, face	(2) Paleness, giddiness	(3) Visual disturbances	(4) Excessive fatigue	(5) Convulsions	(6) Weak/no mov. of fetus
Woman has been sterilized	-0.031***	-0.004*	-0.007***	-0.001	-0.001	-0.002**
	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Observations	201 111	201 111	201 111	201 111	201 111	201 111
Mean Y	0.191	0.116	0.0767	0.0198	0.0470	0.0277

Panel C: Events during last labor	(1) Premature labor	(2) Excessive bleeding	(3) Prolonged labor	(4) Obstructed labor	(5) Breech presentation
Women has been sterilized	-0.000	-0.000	-0.008***	0.003	0.003**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Observations	201 111	201 111	201 111	201 111	201 111
Mean Y	0.104	0.0629	0.144	0.179	0.0262

Panel D: Post-delivery complications	(1) High fever	(2) Abdominal pain	(3) Smelling vag. discharge	(4) Excessive bleeding	(5) Convulsion	(6) Severe headache
Woman has been sterilized	-0.003	0.004	0.001	0.001	-0.000	-0.001
	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)	(0.002)
Observations	201 111	201 111	201 111	201 111	201 111	201 111
Mean Y	0.136	0.179	0.0503	0.0628	0.0371	0.116

Sample: women having given birth in DLHS 2. Information about last pregnancies is recorded only if the last pregnancy took place less than three years before the survey. Standard errors clustered at the district level in parentheses. Controls include age of the woman, education level of the woman and of her husband, age of the couple, religion, caste, wealth, gender of the first-born and village fixed effects. The probability of being sterilized is instrumented by the interaction between the predicted malaria at the district level and whether the first-born is a boy. *** p <0.01, ** p <0.05, * p <0.1. Source: authors.

A.4 The predicted malaria variable

The measure of predicted malaria used in the instrumentation strategy originates from Lauderdale et al. (2014), who have kindly shared their data with us. Climatic conditions generate important variability in the life cycle of the mosquito, affecting both the viability of the malarial parasite and the rate of biting by mosquito. As a consequence, malaria outbreaks display important seasonal variability.[29]

Lauderdale et al. (2014) use the Liverpool Malaria Model of Hoshen and Morse (2004) to simulate malaria incidence following rainfall and temperature variations. Both temperature and rainfall have a non-linear impact on epidemiological risks. The development pace of the malarial parasite within the mosquito requires approximately 111 days with a temperature above 16°C, while the rate of mosquito biting depends on cycles of 37 days with a temperature above 9°C. Above 20°C, temperature decreases adult mosquito survival. Regarding rainfall, the population of mosquitoes relies on the availability of surface water, which depends on rainfall and land-surface heterogeneity. Extremely heavy rainfall might flush mosquito larvae. As a consequence, the incidence of malaria does not linearly reflect increases in rainfall or temperature, but rather reacts in a quite precise way to specific thresholds.

[29] It is particularly the case in Orissa, West Bengal, Jharkhand (north-east India), Gujarat, Rajasthan, Madhya Pradesh and Maharashtra (north-west India).