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Soil Endowments, Production Technologies and Missing Women in India

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Abstract

The female population deficit in India has been explained in a number of ways, but the great heterogeneity in the deficit across districts within India still remains an open question. This paper argues that across India, a largely agrarian economy, soil texture varies exogenously and determines the workability of the soil and the technology used in land preparation. Deep tillage, possible only in lighter and looser loamy soils, reduces the use of labor in cultivation tasks performed by women and has a negative impact on the relative value of girls to a household. The analysis finds that soil texture explains a large part of the variation in women's relative participation in agriculture and in infant sex ratios across districts in India.

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Soil Endowments, Production Technologies and Missing Women in India

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1. Introduction

The deficit of women relative to men in some societies has emerged as the most extreme indicator of gender-based discrimination (Sen 1990). Studies concerned with the demographic gender imbalance have provided evidence on significant effects of economic factors (Rosenzweig and Schultz 1982, Rao 1993, Larsen et al. 1998, Rose 1999, Qian 2008) and of cultural disparities in the perception of women's worth (Das Gupta et al. 2003). However, great geographical differences in population sex ratios remain and are more difficult to explain (Basu 1982, Das Gupta et al. 2003).

This study examines the remarkable geographical heterogeneity in infant sex ratios in India. In India, a country characterized by a severe female population deficit, sex ratios are not male-biased everywhere. They differ substantially across districts, even within the same state and cultural region (Dyson and Moore 1983, Agnihotri 1996). Average district sex ratios for the 0-to-6 year old population are more biased in the North than in the South, and range from a minimum of 766 to a maximum of 1035 females per 1000 males.

I show that in India, where 72 percent of the population is rural, there is a significant and important association between the geographical variation in exogenous soil texture and rural infant sex ratios. I argue that the association can be explained by differences in the economic contributions of women relative to men in agricultural production. In agriculture, the depth of land and seedbed preparation are exogenously determined by the soil texture. Deep tillage of land reduces the need for transplanting, fertilizing and weeding operations, which are typically performed by women (Basant 1987). In areas where deep tillage is required, the lower demand for female relative to male labor is expected to have a negative impact on the perceived relative value of girls to a household (Boserup 1970, Bardhan 1974 1988, Miller 1982, Rosenzweig and Schultz 1982, Bossen 1989, Qian 2008, Alesina, Giuliano and Nunn 2010).

Soil texture is a physical property of the soil that is exogenously defined by geological and meteorological factors and that is not easily modified by land management practices. The soil texture is not a chemical or biological attribute and, by itself, does not determine the quality of soil or the type of crop that can be grown. Instead, the soil texture determines the workability and tillage requirements of the soil. Deep tillage can only be done in light soils of loamy texture but not in heavy soils of clayey texture (Muller and Schindler 1999).

I built on the exogenous variation in soil texture to explain the variation in rural infant sex ratios in India. The identification assumption is that, conditional on weather, soil chemical and biological characteristics and state fixed effects, the relationship between soil texture and rural 0-to-6 year old sex ratios across districts can only be explained by the impact of deep tillage of land on the relative demand for female labor. Because smaller relative female labor contributions in loamy areas make girls relatively more costly, the ratio of girls to boys will be negatively related to the difference between the fractions of loamy and clayey soils.

Identification is obtained from the variation in soil distribution across districts within a same state. The district is the unit of analysis where the impact of deep tillage of land can be isolated from other channels. In India, labor markets are geographically small and migration is limited and occurs mostly within district boundaries. Other geographical differences in income, agricultural yield or cropping patterns, as well as in culture, policy, social and economic variables, are not driven by soil texture and are insignificant across districts within a same state. Therefore, differences in the relative female labor force participation and the infant ratio of girls to boys across districts within a same state could not be explained by those alternative mechanisms.

Consistently, I find that the districts with larger fractions of loamy relative to clayey soils exhibit a lower ratio of female to male children. I also find significantly lower female participation in agriculture and higher stocks of deep plows and draft animals per hectare of land in loamier districts. In contrast, I find no evidence of differences by soil texture in crop yields, crop mix or income once other determinants are properly identified.

Soil texture alone explains 62 percent of the variation across districts within a state in female agricultural labor force participation and 70 percent of the variation in rural 0-to-6 sex ratios. A 10 percentage point difference between the fraction of loamy and clayey soils is associated with a 5.1 percent decrease in female labor force participation as agricultural laborers and a 2.7 percent increase in the rural deficit of girls. The sign and magnitude of the relationship between soil texture, relative female labor force participation and rural infant sex ratios have not changed significantly between 1961 and 2001.

In a related study, I offer additional evidence on investments in health inputs and in the survival of girls. Consistent with the geographical differences in soil texture and in the relative economic value of women in agricultural production, I find that proximate determinants of the infant sex ratios include greater pre-natal sex selection and lower vaccination of girls relative to boys in loamier districts, where labor market opportunities for women are fewer (Carranza 2011).

Since only relative female labor force participation had a significant mediating role, I draw on the effect of soil texture on the demand for female labor to explain the relationship between the geographical variation in relative female labor force participation and infant sex ratios. Using the fractions of loamy and clayey soils as instruments for female shares in the rural work force, I find that an additional 10 percentage point share of female agricultural laborers would increase the relative number of rural 0-to-6 year olds by 44 girls per 1000 boys (from 934 to 978). The magnitude of this effect is comparable to 67 percent of the all India rural deficit of girls, or to almost twice the difference in rural infant sex ratios between the North and South (927 vs. 950). In the North, where the social status of women is lower, a 10 percentage point higher share of female agricultural laborers is estimated to reduce the rural deficit of girls by 74 percent. In the South, where the share of female agricultural laborers is more homogeneous across districts, a similar increase would reduce the rural deficit of girls by 47 percent.

The rest of this paper is organized as follows. Section 2 explains the relationship between soil texture, deep tillage and relative female employment. Section 3 describes the data and baseline district characteristics by soil texture and presents the empirical methodology. Section 4 reports reduced form estimates of the effects of soil texture on sex ratios and relative female labor force participation for all India, within cultural regions and over time. Section 5 examines alternative mediating mechanisms and provides evidence supporting the mediating role of differences in the depth of tillage across soil textures. Section 6 reports instrumental variable estimates of the influence of relative female labor force participation on the sex ratio. Section 7 concludes.

2. Soil texture, deep tillage and relative demand for female labor

To motivate the empirical work, I begin by explaining the role of soil texture in land preparation and crop growth, and the effects of deep land tillage on the demand for female and male labor in agriculture.

2.1. Soil texture and land preparation

Soil texture is a physical property defined by the proportion in which mineral particles of different sizes (small or clay, medium or silt, large or sand) are combined in the soil. It is exogenously determined by geological and meteorological factors and established over millennia, as rain, wind, and temperature decompose rock parent materials.

The texture determines the workability of the soil, its compressibility, compaction, bearing strength, and shrink-swell potential.[2] Finer soils are heavier, stickier when wet and harder when dry. Coarser soils are lighter and looser. When soils are so fine-textured as to be classified as clayey, they exhibit properties which make deep tillage difficult. Instead, medium-textured loamy soils are easier to break at any moisture level. Deep tillage can only be done in loamy soils but not in clayey soils (USDA 1993, Muller and Schindler 1999, Troeh and Thompson 2005).[3]

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[2] Compressibility is the resistance against volume decrease when the soil is subjected to a mechanical load. Compaction is the volume of pore space a soil can retain under a given load. Bearing strength is the maximum pressure between the foundation and the soil which does not produce shear failure. Shrink-swell potential is the extent to which the soil shrinks as it dries out or swells when it gets wet.

[3] Tillage in loamy soils breaks up the soil to a depth of 6 to 12 inches. Tillage in clayey soils is limited to breaking up clods and lumps in the top 2 to 6 inches of soil (Throe, Hobbs and Donahue 1991).

The physical functioning of clayey and loamy soils has indeterminate consequences for plant growth. The texture influences plant development indirectly by defining the inherent physical mechanics of the soil, its porosity, permeability and cation exchange capacity.[4] Fine clayey soils have poor aeration and water intake, but high water and nutrient retention. Coarse loamy soils have good aeration and water absorption, but leach water and nutrients. Because clayey and loamy soils have both advantages and limitations for plant growth, there is no such thing as an intrinsically superior soil texture.

The quality of the soil and its suitability for a certain crop are not shaped by the soil texture. Although the texture determines the mechanics of the soil, it does not define the ultimate ability of the soil to retain moisture and nutrients and to permit air and water movement. The organic matter and geological precursors of the soil have a more fundamental influence. Likewise, the texture does not determine the level of aeration and conductivity or the amount of water and nutrients present in the soil at a given moment. Meteorological (rainfall, temperature), hydraulic (water table), and technological (land management) factors play a more important role.[5]

Conditional on other chemical, biological and meteorological factors, only the depth of tillage is exogenously determined by soil texture. The chemical,

[4] Porosity is the amount of open spaces between the solid grains of soil. It defines the water retention capacity. Permeability is the degree of connectivity between soil pores. It defines the water intake rate. Cation exchange capacity is the innate ability of a soil to retain cations, some of which are plant nutrients.

[5] For instance, a sandy soil texture is inherently highly porous and permeable. However, the combination of sand grains with organic matter and iron/aluminum oxides increases the water retention capacity of sandy soils. Similarly, deep tillage and turning over the soil reintegrates soil moisture, helps developing a compact pan and can reduce soil permeability radically, even in sandy soils. Sandy soils are also likely to retain moisture if they are close to a water table and are saturated with water for extended periods.

biological and physical properties that define the quality of the soil and influence plant growth are not determined by soil texture and are not exogenous. They are easily and frequently modified in order to improve the inherent soil properties, make the soil better suited for a wider variety of crops and increase crop yield. In contrast, the particle-size composition that determines the workability of the soil is difficult to change in the field. Land management and land use have minimal impact on soil texture.

2.2. Deep tillage and demand for labor

Deep tillage of land, only possible in coarser-textured loamy soils, is a gender-biased labor saving technology. It reduces both total employment as well as the employment opportunities of female relative to male workers in agriculture. Deep tillage consists in breaking and turning over the soil, which facilitates root development, reintegrates moisture, nutrients and organic matter, and uproots weeds. Deep tillage increases the duration of land preparation. However, deep tillage reduces the need for transplanting, fertilizing and weeding operations (Burton and Reitz 1981, Troeh and Thompson 2005). In agriculture, these cultivation activities are typically performed by women more than by men. In contrast, relatively more men than women prepare the land (Basant 1987, Foster and Rosenzweig 1996).[6] Given the greater labor intensity of cultivation relative to land preparation, the negative impact of deep tillage on the demand for labor in cultivation offsets its positive effect on land preparation. Moreover, given the pattern of gender-segregation across tasks, deep tillage has a larger negative impact on the demand for female labor than for male labor. As a consequence,

[6] The occupational distribution of workers has been explained by productivity differentials and statistical discrimination. Differences in productivity sort workers across tasks in the piece-rate sector. Statistical discrimination and limited knowledge of the true variance in productivity lead to task-specialization in the time-wage sector (Foster and Rosenzweig 1996).

deep tillage reduces both female and male employment and female relative to male employment (Burton and Reitz 1981, Basant 1987).

The effects of the depth of tillage are limited to those on the use of labor across the sequence of tasks. No other significant differences by depth of tillage are known (Binswanger 1986, Pingali et al. 1987, Ellis 1992). Relative to shallow tillage in clayey soils, deep tillage in loamy soils has no significant effects on cropping cycles, cropping patterns, cultivated area or agricultural yield. Although the labor released by deep tillage could be employed in increasing the number of cultivation cycles or in growing a higher value crop mix, this is prevented by factors such as seasonal climatic variations and soil chemical and biological attributes. Similarly, in India, where labor is abundant relative to land, the quality and availability of soils are more binding constraints for the expansion of agricultural lands. Furthermore, the depth of tillage is exogenously and optimally determined by soil texture. An increase in yield would only be possible if moving from no-tillage to tillage of land, from shallow to deep tillage of loamy soils, or from deep to shallow tillage of clayey soils (Muller and Schindler 1999, Troeh and Thompson 2005).[7]

As a result, when separate determinants are properly identified, the effect of deep tillage on the technological demand for labor is expected to define a significant negative association between coarse-textured loamy soils, total employment and female relative to male employment in agriculture. No other soil quality, yield or crop mechanisms are expected to mediate the relationship

[7] Deep tillage is not only possible but optimal in loamy soils, as is shallow tillage in clayey soils. Deep tillage reintegrates the nutrients and moisture leached down in coarse-textured and loose loamy soils. Shallow tillage facilitates plant development in poorly aerated and drained fine-textured and heavy clayey soils. Instead, deep tillage in clayey soils prevents germination and breaks the hard pan, and shallow tillage in loamy soils limits fertility and plant growth.

between soil texture, depth of tillage and labor market opportunities in agriculture.

3. Empirical strategy

In what follows, I describe the main identification strategy and the data used in the analysis.

3.1. Identification

To distinguish the effect of deep tillage, I build on the exogenous geographical variation in soil texture. I estimate:

$$Y_{sd} = \alpha_{0s} + \alpha_1 T_{L\,sd} + \alpha_2 T_{C\,sd} + \alpha_3 X_{sd} + \varepsilon_{sd} \qquad [1]$$

Where Y_{sd} is the ratio of girls to boys or the employment outcome of interest in district d in state s; $T_{L\,sd}$ and $T_{C\,sd}$ are the fractions of district area in loamy and clayey soil textures (the omitted texture category is sandy soils); and X_{sd} controls for other factors that may have an independent influence on sex ratios, agricultural employment and labor force participation, including population demographics (composition by area, religion and caste) and determinants of agricultural yields and cropping patterns (soil chemical properties and meteorological variables). Finally, I cluster standard errors at the state level.

For each outcome, α_{0s} is a state fixed effect. Therefore, within a same state, my estimates compare districts that have different area fractions in loamy and clayey soils, controlling for sandy soils. The difference between the coefficients on the fraction in loamy and clayey soils $(\alpha_1 - \alpha_2)$ is interpreted as the effect of the deep tillage technology. The identification assumption is that conditional on state fixed effects, demographics and other exogenous controls, the fraction of loamy relative to clayey soil texture in a district is associated only with the extent of deep tillage in land preparation.

The district-level state-fixed-effect estimation allows properly isolating the impact of soil texture. Other influences that affect preferences for child gender and the demand and supply of labor operate at more aggregate or disaggregate levels. Large differences in culture, religion, policy, social and economic factors challenge cross-state comparisons; and substantial mobility within a same district affects cross-village or cross-household comparisons. In contrast, in India, districts are more homogeneous within a same state, labor markets are geographically small and most migration occurs within district boundaries (Dyson and Moore 1983, Foster and Rosenzweig 2001).

It could still be contended that important cross-district differences remain within a state, including differences in weather, income, agricultural yields, and cropping patterns. A large literature has studied their impact in sex ratios and in agricultural labor force participation, particularly female. High rainfall has been associated with high relative demand for female labor and high ratio of female to male population (Rosenzweig and Schultz 1982, Mbiti 2007); high agricultural yield with low relative female labor force participation and high ratio of female to male children (Rose 1999); and high household income with low relative supply of female labor and low child sex ratios (Krisanji 1987, Das Gupta and Shuzhuo 1999). An association has also been established with rice and wheat, the two dominant crops in India. Areas where wheat is cultivated exhibit lower labor force participation in agriculture, smaller female labor contributions and stronger son bias than areas where rice is grown (Bardhan 1974, Miller 1982, Dyson and Moore 1983).

Nevertheless, remaining differences in rainfall, agricultural yields, household income, and rice and wheat cultivation across districts within a same state cannot explain the negative relationship between loamy soil texture and labor force and sex ratio outcomes. The variation in rainfall and other weather and climatic conditions across districts is exogenous, and income, yield and crops are not expected to vary systematically with soil texture conditional on other chemical, biological and meteorological determinants. Moreover, depictions offered by others emphasize that when rice and wheat crops are cultivated in rotation in a same plot (so that soil texture is the same), differences in the tasks performed by men and women are small and insignificant (Sethi 1991, Varma 1992). In contrast, for a given crop, differences in labor inputs, tasks performed and methods used in land preparation and sowing are observed between loamy and clayey soils. For instance, in rice cultivation, frequently identified with greater relative use of female labor inputs, women have a more significant role in clayey lands where rice is broadcast than in loamier lands where rice is sown at depth behind the plow (Miller 1982).

Alternatively, it could be argued that workers, particularly female, may migrate from districts with greater fractions of loamy soils to districts with smaller fractions of loamy soils where deep tillage is less practiced and employment opportunities in agriculture are greater. Although in India most migration occurs within a district, 7.8 (1.6) percent of women (men) in a district are immigrants from a different district within the same state.[8] If cross-district migration were not exogenous to soil texture, the estimated effect of deep tillage would suffer from attenuation bias and should be interpreted as a lower boundary of the actual effect. However, I find no significant differences by soil texture, across districts within a same state, in the percentage of immigrants, the location of previous residence or the reason for migration. To the extent that there are no systematic differences in migration by soil texture, it is not a serious threat for identification.

3.2. Data

I construct a district-level dataset that combines information collected from multiple sources (see Appendix Data Sources). Table 1 provides summary statistics for selected variables, for all districts as well as by soil texture, conditional on state fixed effects.

For all the analysis, I use soil texture data from the 1991 Soils of India. Soil texture within a district is described by the fraction of district area in sandy, loamy and clayey soils. In India, there is large variation in soil textures across districts within a state and across states. Relative to loamy soils, clayey soils are more rarely found in the North (56 vs. 96 percent of districts) than in the South (79 vs. 99 percent of districts). On average, 66 percent of a district's area is covered with loamy soils, 22 percent with clayey soils and 11 percent with sandy soils.

[8] NSS records migration in the place of enumeration and based on the concept of change in the usual place of residence. On average, 39 (6.8) percent of women (men) in a district migrated, and 74 (59) percent of them migrated within the same district.

To establish the impacts of soil texture on sex ratios and labor force outcomes, I use demographics for total and under-six-years-old populations, and labor force participation for total population from the 2001 Census of India. Since no census micro-data are available, I complement the census information with economic and demographic data and labor force participation from the 1999-2000 National Sample Survey (NSS), which I use to generate finer district cross-tabulations by age and agricultural task.[9]

Geographically, the spatial variation in the relative female labor force participation rate and in the ratio of female to male children resembles the distribution of soils by clay content. Greater fractions of loamy relative to clayey soils are also significantly associated with a higher percentage of scheduled tribes and a lower percentage of scheduled castes and Jain population (Table 1, Panel A). If omitted, their influence would attenuate the estimated effect of soil texture.[10] In contrast, no significant differences by soil texture are found in the percentage of rural, Muslim and Sikh populations (not reported), in household size, or in female and male migration rates and wages.

Controls for weather come from the Indian Meteorological Department and markers of soil chemical and biological attributes come from the 1991 Soils of India. No significant differences by soil texture in rainfall, temperature and soil nutrients (nitrogen, phosphorus and potassium) are observed across districts within a same state (Table 1, Panels B and C). Significant differences in soil pH

[9] NSS is not used throughout the study because it covers a smaller sample of districts and is not representative at the district level. However, NSS is representative at the region level. In rural areas, regions overlap with most district boundaries. I use census for basic regressions and NSS for more detailed analysis.

[10] Women's social value is high in scheduled tribes and low in Jain and scheduled castes (Agnihotri 1996). However, I find that the infant sex ratios of scheduled and Jain groups do not vary with soil texture (not reported).

are found, but their sign cannot be explained by soil texture.[11] As reflected in soil nutrients and pH, there is no indication that soil texture would shape the quality of the soil or its suitability for a certain crop.[12]

In order to explore the mediating mechanisms, I use information on agricultural inputs from the 2000-2001 Agricultural Census and Input Survey, as well as crop production data from the 1997-2001 Indian Agricultural Statistics. Although there is significant geographical variation in soil texture, 487 out of 593 districts in India implement rice-wheat rotations. Wheat-rice dichotomizations of cropping and socio-cultural systems do not match the pattern of geographical variation in soil texture. I discuss findings by soil texture regarding these outcomes in the next section.

I adjust all monetary values using the 1999-2001 Consumer Price Index Numbers for Agricultural and Rural Laborers. Finally, I match administrative divisions from all datasets to district boundaries from the 2001 census. I obtain a maximum sample size of 577 districts, with complete information available for 418 districts.

[11] In the sample examined, districts with greater fractions of loamy relative to clayey soils are more likely to have acidic soils (pH lower than 7.5) and less likely to have alkaline soils (pH higher than 7.5). Instead, higher pH soils are expected in loamier areas because, keeping other factors constant, loamy soils have intrinsically lower cation exchange capacity than clayey soils.

[12] Rice grows better in acidic to slightly alkaline soils (pH 4.5-7.5). Wheat grows better in alkaline soils (pH 7.0-8.5). Controlling for soil pH, no significant differences in cultivation and productivity of rice and wheat crops across soil textures should be found.

4. Main results

Here I report and discuss reduced form results from OLS estimations at the district level. I compare outcomes of interest across districts with different fractions in loamy and clayey soils, controlling for sandy soils, state fixed effects and other independent influences. First, I establish the relationship between the fractions of loamy and clayey soil textures in a district, the ratio of female to male children, and female and male employment in agriculture. Later, I explore whether soil texture has an impact on alternative mediating mechanisms, including the practice of deep tillage, the importance of rice and wheat crops, and agricultural yield and income.

4.1. Soil texture and infant sex ratio

I begin by describing the relationship between soil texture and the ratio of 0-to-6 year old female to male children who reside in rural areas. The 2001 Census of India reports enumeration totals only for population of all ages and under six years old. I focus on the population younger than six years old because for that age group the ratio of females to males is more likely to result from differential treatment than from migration.[13] The average rural district sex ratio is of 934 female per 1000 male children under six years old.

In Table 2, I report regression estimates for a sample of districts that have complete data. Soil texture variables have a highly significant joint effect on rural infant sex ratios in all specifications. Furthermore, the difference between the fraction of loamy and clayey soils in a district is negatively related to the

[13] Sex ratio at age 0 is not reported. The sex ratio at age 0 is typically used as a proxy for the sex ratio at birth because birth records in India are deficient.

ratio of female to male children. In the basic regression with only state fixed effects (col. 1), I find that differences in soil texture across districts within a same state explain 70 percent of the variation in infant sex ratios. A 10 percentage point higher fraction of loamy relative to clayey soils is associated with an increase of 1.8 percent in the deficit of girls. A larger effect is found once the regression is fully specified. Controlling for the independent influence of demographics, weather, soil nutrients and pH (col. 4), a 10 percentage point difference between the fraction of loamy and clayey soils increases the deficit of girls by 2.7 percent.

The larger estimated effect in the full specification relative to the basic specification indicates that other influences have a positive rather than negative association with the ratio of girls to boys. If omitted, they would bias down the magnitude of the estimated effect of soil texture. In Appendix Table A.1, similar results are obtained when the maximum sample available is used and when controls for income and crop yield, instead of controls for soil attributes, are included. For the rest of the analysis I use the full available sample and the full specification as indicated in eq. [1].

4.2. Soil texture and agricultural employment

I turn to examine the relationship between soil texture and employment in agriculture. The census reports the total number of workers, separated by area and occupation but not by age. Female and male labor force participation rates are defined as the ratio of workers of all ages to the total population within the corresponding gender group. The average district rural female (male) labor force participation rate is 0.33 (0.52) percent; 0.27 (0.36) percent of women (men) in rural areas work in agriculture and 12 (13) percent work as laborers.

I focus on agricultural workers and laborers in rural areas. Agricultural workers are all workers, landed or landless, employed in farming and cultivation, in their own or in other's land, with or without pay. Agricultural laborers are agricultural workers, landed or landless, employed in other persons' lands. Differences by soil texture in employment opportunities in agriculture are driven by differences in the participation of agricultural laborers. Given the technological demand for labor across soil textures, the owners of clayey plots are more likely to employ their labor in their own land, while the owners of loamy plots and the landless are more likely to employ (part or all) their labor in others' plots. As a result, larger variation in the participation of agricultural laborers than in agricultural workers is expected across soil textures. The variation in participation rate of agricultural laborers is a better measure of the impact of soil texture.

In Table 3, col. 1 to 4, I present results from the regression of labor force participation rates, for female and male agricultural workers and laborers, on soil texture. I find that the soil texture fractions significantly explain labor force participation in agriculture. The difference between the fraction of loamy and clayey soils has a negative impact on labor force participation, particularly on female agricultural laborers. Soil texture explains 62 (54) percent of the within-state variation in the labor force participation of female (male) laborers. A 10 percentage point difference between the fraction of loamy and clayey soils reduces the participation of female (male) laborers by 5.1 (3.6) percent. Effects on female and male agricultural workers are smaller, 1.9 and 0.92 percent respectively.

Overall, the labor force participation of rural women is driven by their participation in agriculture. The impact of soil texture on total rural female labor is significant and similar to its influence on agricultural female workers. In contrast, in rural areas men have greater labor market opportunities than women outside agriculture. The labor force participation of rural men is unaffected by soil texture (not reported).

In order to examine the effects of soil texture on relative female labor force participation, I obtain the share of female agricultural workers and the share of female agricultural laborers in the total rural work force. By using total rural labor force in the denominator, these measures account for differences between men and women in labor opportunities outside agriculture. Soil texture significantly predicts the share of females in the rural work force and has a negative impact on their relative labor force participation. The fractions of loamy and clayey soils in a district explain 69 (58) percent of the variation in the share of female agricultural laborers (workers). In Table 3, col. 5 and 6, a 10 percentage point difference between the fraction of loamy and clayey textures reduces the share of female agricultural laborers (workers) by 5.3 (1.97) percent.[14]

4.3. Soil texture, infant sex ratio and relative female labor force participation within cultural regions

I continue by contrasting the effects of soil texture in sex ratio and relative female labor force participation across cultural systems. In India, there is a marked difference in cultural arrangements between the North and the South. Compared to the South, cultural practices in the North of India marginalize women and

[14] Similar results are obtained in regressions for the ratio of female to male labor force participation rates as agricultural workers and laborers. However, the ratio of female to male labor force participation rates overestimates the relative labor contribution of women because more men work outside agriculture in loamier areas.

seclude them from work.[15] I assign districts in the census to northern or southern regions and replicate the analysis for each sub-sample.[16] I choose this strategy over the inclusion of controls for proxies of culture because these are not consistently measured and are potentially endogenous.[17]

I find that the effects of soil texture on the ratio of female to male children and on the relative labor force participation of women are more significant and about twice larger in the North than in the South. In the North (South), the soil texture fractions explain 73 (38) percent of the variation in sex ratios, 55 (64) percent of the share of female agricultural workers, and 66 (48) percent of the share of female agricultural laborers. In Table 4, a 10 percentage point difference between the fraction of loamy and clayey soils is associated with a reduction of 2.4 (0.36) percent in the ratio of girls to boys in the North (South). It is also associated with reductions of 2.6 (1.9) percent in the share of female agricultural workers and 6.2 (3.9) percent in the share of female agricultural laborers in the rural work force in the North (South).

The more significant and larger influence of soil texture in the North can be explained by the greater geographical variation in soil texture in that region. In the North, 56 percent of the districts has clayey soils and 95 percent has loamy soils. In the South, 90 percent has clayey soils and 100 percent has loamy soils. The

[15] In the North, the low status of women is attributed to the practices of exogamy, hypergamy, patrilocality, dowries, low age at marriage, and greater presence of Muslim groups. In the South, the more favorable conditions for women are associated to the practices of endogamy, homogamy, matrilocality, bride price or no transfers at marriage, older age at marriage, and shorter distance between natal and marital residence.

[16] I follow the standard division of cultural regions in India, defined by whether the district falls to the north or the south of the Satpura and Chota Nagpur Hills (Dyson and Moore, 1983; Sopher, 1980).

[17] For instance, the distance of female migration because of marriage (a proxy for patrilocality) may be shorter when women's labor contributions and the share of women in the population are higher.

estimates suggest that the impact of soil texture counteracts the lower socially perceived returns to having daughters in the North. A dominant influence of cultural arrangements would have resulted in smaller differences by soil texture in sex ratios and female labor force participation in the North than in the South.

4.4. Soil texture, infant sex ratio and relative female labor force participation over time

Finally, I explore how the influence of soil texture has evolved over time. I use census data for three decades (1961, 1981 and 2001) on population of all ages and under nine years old, and agricultural workers and laborers of all ages.[18] Soil texture data are available only for 1991, but it is reasonable to assume that the texture remained unchanged. During the 50-year period examined, the share of female agricultural workers fluctuated between 24 and 29 percent, the share of female laborers increased from 7.6 to 16 percent, and the 0-to-9 rural sex ratio decreased from 977 to 934 girls per 1000 boys under nine years old.

In Table 5, col. 1 to 3, I report estimates from pooled regressions of the 0-to-9 rural sex ratios on soil texture. I also report results from the comparison of estimated coefficients relative to 1961. I limit the sample to districts that have information for the entire period. Soil texture fractions significantly explain the rural 0-to-9 ratio of girls to boys. Between 1961 and 2001, the share of the variation in the sex ratio explained by soil texture fractions alone fluctuated between 72 and 64 percent. The marginal effect of the difference between loamy and clayey soil fractions declined from -5.2 percent to -2.4 percent of the 0-to-9 deficit of girls, but the change was not statistically significant.

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[18] Information on population under six years old was not reported before 2001. In 1991, only information on main (not total) agricultural workers and laborers was reported.

In Table 5, col. 4 to 6, I present similar estimates for the share of female agricultural workers among all rural workers. Between 1961 and 2001, the fraction of the variation in the share of female agricultural workers explained by soil texture increased from 66 to 71 percent. Instead, the estimated effect of differences between loamy and clayey soil texture fractions remained unchanged, between -1.9 and -2.1 percent. Similarly, the fraction of the variation in the share of female laborers explained by soil texture increased from 69 to 73 percent. The estimated marginal effect declined from -7.9 to -5.1, but no statistically significant change was recorded (not reported).[19]

The results suggest that soil texture has a permanent influence on the geographical variation in rural sex ratios and relative female labor force participation. Although between 1961 and 2001 the percentage of rural population decreased (from 86 to 72 percent), new labor market opportunities in the urban sector have not lessen the impact of soil texture. Other factors may explain the decline in sex ratios over time.[20]

5. Mediating mechanisms

Differential preferences for male versus female children and differential female and male labor force participation in agriculture by soil texture can be explained

[19] Results obtained for total rural female labor are similar. The fraction of the variation explained by soil texture is increasing, and the marginal effect remains unchanged.

[20] Differences in soil texture cannot directly account for the increasing share of female agricultural laborers and the declining ratio of girls to boys in rural and urban areas. In fact, the female labor force participation rate is smaller in urban than in rural areas, 0.18 and 0.36, respectively.

through multiple channels. In what follows, I establish which mechanisms have a significant mediating role.

5.1 Soil texture, cropping patterns, agricultural yields, household expenditure and land ownership

First, I examine differences by soil texture in cropping patterns, agricultural yields and various proxies of income. The Indian Agricultural Statistics report district agricultural production and area cultivated disaggregated by crop. I obtain 5-year averages between 1997 and 2001.[21] I use data on the gross cultivated area in rice and wheat (in tons), the yields of rice and wheat (in tons per hectare), and the ratio of rice to wheat area and rice to wheat yield.[22] These measures inform on the scale of production, the productivity of the soil, and the suitability of the soil for rice and wheat crops. Statistics on GDP or household income at the district level are not produced in India. Instead, I use data from the 1999-2000 National Sample Survey to obtain the average real per-capita household expenditure, the percentage of households that own land, and the average extension of land owned by a household in a district. I examine these indicators in lieu of income.

In Table 6, I show regression results for a subset of outcomes. Soil texture fractions do not explain the variation in any of the outcomes reported or examined. Moreover, the fraction of loamy relative to clayey soils has insignificant impacts on all outcomes studied. My estimates indicate that once other independent influences are accounted for, differences across districts within

[21] This period corresponds to the years of birth of the population under six years old.
[22] The gross area counts the area sown as many times as there are sowings in a year. In contrast, the net area counts only once the area sown more than once in the same year.

a same state in agricultural production, soil productivity, cropping patterns, household consumption and ownership of land are not explained by soil texture.

5.2 Soil texture, deep tillage and labor use across tasks

Next, I examine differences by soil texture in the method of land preparation and in the use of labor across agricultural tasks. Although district-level data on the depth of tillage are not available, data on inputs used in land preparation are a good proxy. I obtain stocks of livestock and equipment used per hectare of area cultivated from the 2000-2001 Agricultural Census and Input Survey. I obtain the share of male and female workers by task over all agricultural workers from the 1999-2000 National Sample Survey.

In Table 7, Panels A and B, I report estimates from the regression of equipment used in land preparation and other cultivation tasks on soil texture. The use of a particular land preparation technology is exogenously determined by soil texture. Heavy plows can only be employed in deep tillage (ASAE 2003). Consistently, I find that a 10 percent higher fraction of loamy relative to clayey soils is significantly associated with 4.1 percent more heavy plows and 5.3 percent more buffalos (used to draw the plows). Soil texture alone explains 60 and 62 percent of the variation in the use of heavy plows and buffalos, respectively. In contrast, the stocks of light plows and other equipment used in shallow tillage or in other cultivation tasks do not vary with the fraction of loamy relative to clayey soils. No significant differences by soil texture are found in the stocks of animals not used in cultivation.

In Table 7, Panel C and D, I report results for the composition of workers by task and gender. I find a smaller share of workers performing cultivation tasks and a larger share preparing the land in loamier districts. In Panel C, a 10 percent higher fraction of loamy relative to clayey soils is associated with a 1.1 percentage point shift in the composition of agricultural workers from cultivation to land preparation. In Panel D, fewer female and male workers in cultivation and significantly more male workers in land preparation are found in loamier districts. Women's participation in land preparation is generally low. On average, 1.4 percent of all workers are women in land preparation, compared to 16 percent who are men in the same activity. The share of women in land preparation does not vary significantly with soil texture.

The evidence examined suggests that the depth of tillage, not the use of capital or the use of the plow, mediates the impact of soil texture. First, soil texture explains differences in capital used in land preparation only, not across all tasks. Second, soil texture has a significant effect in the use of heavy plows only, not in the use of plows more generally. Third, the share of female workers in land preparation is always low. Soil texture has no significant impact in the use of female labor in land preparation.[23]

In summary, I find evidence that deep tillage has a significant mediating role and that there is no other significant mediating mechanisms. Any differences across loamy and clayey soils in female relative to male labor force participation are explained only by the effect of deep tillage. Other district characteristics that may influence female labor force participation and sex ratios do not vary significantly with soil texture.

[23] At all times, men prepare the land and women take care of other operations. Given the gender-segregation by task, the deep plow reduces the relative use of female labor by affecting the demand for labor in cultivation relative to land preparation

6. Instrumental variables estimates of the effect of relative female labor force participation on the infant sex ratio

In this section, I assess the influence of relative female labor force participation on the ratio of girls to boys under six years old. Because female labor force participation and infant sex ratios may be jointly determined, I exploit the fractions of district area in loamy and clayey soils as exogenous instruments for the variation in relative female employment. Identification requires soil texture to influence the sex ratio exclusively through the effect of deep tillage. This is a plausible assumption. Conditional on state fixed effects and other controls, the exogenous variation in soil texture correctly identifies the effect of deep tillage on the technological demand for female labor in agriculture.

In Table 8, I report instrumental variable estimates for the all-India sample and for North and South regions separately.[24] Using soil texture fractions as instruments, I find that a 10 percentage point increase in the share of female agricultural workers results in 28 additional girls per 1000 boys. A similar increase in the share of female agricultural laborers results in 44 additional girls per 1000 boys. Within regions, I estimate that a 10 percentage point higher share of female agricultural workers in the rural work force is associated with 34 (14) additional girls per 1000 boys in the North (South). A similar increase in the share of female agricultural laborers would result in 54 (23) additional girls per 1000 boys in the North (South).

[24] In the first stage, soil texture fractions significantly predict the share of female workers and laborers in the rural work force (Table 3 and Table 4).

To get a sense of these magnitudes, the observed all-India rural deficit is 66 girls per 1000 boys, and the difference in 0-to-6 year old rural sex ratios between the North and South is 23 girls per 1000 boys.[25] The estimated effects of female agricultural laborers are comparable to 70 percent of the all-India deficit of girls, 74 percent of the deficit of girls in the North and 47 percent of the deficit of girls in the South. Effects of this order raise the 0-to-6 rural sex ratio to above the average natural outcome of 950 girls per 1000 boys in the developed world (Johanson and Nygren 1991, Coale 1991).

7. Conclusions

This study offered an economic explanation for the spatial heterogeneity in the rural 0-to-6 year old sex ratios in India. Deep tillage, only possible in areas with loamy soil texture, reduces female relative to male employment and has a negative influence in the ratio of female to male children.

I estimated that soil texture explains 62 percent of the within-state variation in female agricultural labor force participation and 70 percent of the variation in 0-to-6 year old sex ratios. A 10 percentage point greater fraction of loamy relative to clayey soils was associated with a 5.1 percent lower share of female agricultural laborers and a 2.7 percent lower ratio of female to male children.

The relationship between soil texture, relative female labor force participation and the ratio of girls to boys was significantly stronger in the patriarchal North of India than in the more gender-equalitarian South. Moreover, the relationship

[25] In the North and South there is a deficit of 73 and 50 girls per 1000 boys, respectively. The average rural 0-to-6 female to male ratio is 927 for the North and 950 for the South.

between soil texture, relative female labor force participation and the ratio of female to male children has not significantly changed between 1961 and 2001.

Using soil texture fractions as instruments for female labor, I found that a 10 percentage point lower relative female employment in deep plow agriculture resulted in a loss of 44 girls per 1000 boys, comparable to 67 percent of the deficit of girls.

The results of this study suggest that although other factors may improve the absolute survival chances of girls, their relative disadvantage in survival will remain as long as the gender gap in labor market opportunities persists.

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Table 1: Selected District Characteristics by Soil Texture

	(1)	(2)	(3)	(4)	
	All	Relative to Sandy Soils			
	Districts	Loamy	Clayey	(2)-(3)	Obs.
Panel A: Demographic and Economic					
% Scheduled tribes	0.18	0.20***	0.10*	0.100***	577
	[0.28]	(0.044)	(0.046)	(0.036)	
% Scheduled castes	0.16	-0.065***	-0.039*	-0.026**	577
	[0.098]	(0.016)	(0.016)	(0.013)	
% Jains	0.0012	-0.00082	0.00030	-0.0011*	577
	[0.0034]	(0.00082)	(0.00085)	(0.00066)	
Household size	6.35	0.077	-0.10	0.18	561
	[0.91]	(0.18)	(0.19)	(0.14)	
Migration rate of men	0.068	-0.027	-0.032*	0.0050	561
	[0.066]	(0.015)	(0.015)	(0.011)	
Migration rate of women	0.39	-0.056	-0.080*	0.024	561
	[0.19]	(0.039)	(0.040)	(0.029)	
Wage rural male workers, in real Rs	74.5	7.03	-0.37	7.40	558
	[35.5]	(6.67)	(6.87)	(4.96)	
Wage rural female workers, in real Rs	53.8	-15.1	-28.8*	13.7	543
	[50.0]	(13.5)	(13.8)	(9.87)	
Panel B: Weather					
Temperature, 30-year average, in C	25.1	-1.15**	-0.65	-0.51	440
	[3.00]	(0.39)	(0.41)	(0.33)	
Rainfall, 50-year average, in mm	1350.1	94.0	-19.3	113.3	584
	[898.8]	(144.6)	(148.7)	(117.4)	
Panel C: Soil Nutrients and pH					
Nitrogen, in ppm	21874.4	2135.0	388.6	1746.4	419
	[20102.4]	(4406.0)	(4631.7)	(3405.8)	
Phosphorus, in ppm	8150.3	2227.9	3966.9*	-1739.0	419
	[6696.6]	(1512.7)	(1590.2)	(1169.3)	
Potassium, in ppm	3316.6	626.5	-188.9	815.4	419
	[4097.4]	(753.6)	(792.2)	(582.5)	
4.5<pH<5.5, dummy	0.24	0.16	0.17	-0.012	419
	[0.43]	(0.11)	(0.11)	(0.084)	
5.5<pH<6.5, dummy	0.22	-0.12	-0.34**	0.22**	419
	[0.42]	(0.12)	(0.13)	(0.092)	
6.5<pH<7.5, dummy	0.12	0.20*	-0.12	0.32***	419
	[0.32]	(0.092)	(0.097)	(0.071)	
7.5<pH<8.5, dummy	0.28	-0.22	0.35**	-0.57***	419
	[0.45]	(0.12)	(0.13)	(0.092)	
8.5<pH<9.5, dummy	0.14	-0.017	-0.065	0.048	419
	[0.35]	(0.093)	(0.098)	(0.072)	

* p<0.05, ** p<0.01, *** p<0.001.

Note: Column 1 reports average and standard deviation. Columns 2 and 3 report coefficients from the regression of indicated variables on the fraction of district area in loamy and clayey soils (excluded category: sandy soils), conditional on state fixed effects. Column 4 reports the difference between the coefficients in columns 2 and 3.

Table 2: Rural 0-to-6 Sex Ratio on Soil Texture

	(1)	(2)	(3)	(4)
	Dependent Variable: Rural 0-to-6 Sex Ratio			
Loamy soils	26.2**	18.6*	7.14	2.02
	(9.39)	(9.05)	(8.39)	(8.54)
Clayey soils	39.4***	38.1***	27.2**	20.2*
	(9.82)	(9.44)	(8.62)	(9.01)
Loamy soils - Clayey soils	-13.2*	-19.5***	-20.1***	-18.2***
	(7.19)	(7.04)	(6.24)	(6.68)
F-test for soil texture	8.07	8.80	7.26	4.37
p-value	0.00	0.00	0.00	0.01
R-squared	0.70	0.73	0.80	0.81
F	48.57	49.63	51.40	41.57
Observations	365	365	365	365
Variable Means				
Dependent variable	924.7	924.7	924.7	924.7
Loamy soils	0.68	0.68	0.68	0.68
Clayey soils	0.22	0.22	0.22	0.22
Weather	No	Yes	Yes	Yes
Demographics	No	No	Yes	Yes
Soil nutrients and pH	No	No	No	Yes
State fixed effects	Yes	Yes	Yes	Yes

* p<0.05, ** p<0.01, *** p<0.001

Note: Dependent variable: ratio of females per 1000 males in the 0-to-6 age group. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils excluded). Other controls: Weather: temperature (30-year average of daily mean temperature, in Celsius) and rainfall (50-year average of daily accumulated rainfall, in mm). Demographics: district area (in ha), percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh, and Jain population. Soil attributes: nitrogen, phosphorus, potassium in the top 25cm of soil (in parts per million, ppm) and pH (dummies for pH values of 4.5 to 5.5, 5.5 to 6.5, 6.5 to 7.5, 7.5 to 8.5, 8.5 to 9.5).

Table 3: Female and Male Labor Force Participation Rates and Relative Female Agricultural Labor Force Participation on Soil Texture

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable:					
	Female Agricultural		Male Agricultural		Female Agricultural To Total Rural Workers	
	Workers	Laborers	Workers	Laborers	Workers	Laborers
Loamy soils	0.037	-0.019	0.0086	-0.021	0.038	-0.020
	(0.026)	(0.018)	(0.018)	(0.014)	(0.024)	(0.018)
Clayey soils	0.089**	0.056**	0.043*	0.034*	0.095***	0.062**
	(0.027)	(0.019)	(0.019)	(0.015)	(0.025)	(0.019)
Loamy soils - Clayey soils	-0.052***	-0.076***	-0.035***	-0.054***	-0.057***	-0.082***
	(0.020)	(0.014)	(0.014)	(0.011)	(0.019)	(0.014)
F-test for soil texture	6.12	15.27	4.00	12.02	8.15	17.58
p-value	0.00	0.00	0.02	0.00	0.00	0.00
R-squared	0.73	0.72	0.57	0.68	0.70	0.67
F	27.51	25.28	13.56	21.18	23.37	20.68
Observations	365	365	365	365	365	365
Variable Means						
Dependent variable	0.27	0.15	0.38	0.15	0.29	0.16
Loamy soils	0.68	0.68	0.68	0.68	0.68	0.68
Clayey soils	0.22	0.22	0.22	0.22	0.22	0.22
Weather	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

* p<0.05, ** p<0.01, *** p<0.001.

Note: Dependent variables: female and male agricultural workers and agricultural laborers as percentage of all-age female and male rural population; ratio of female agricultural workers and agricultural laborers to total workers in rural areas. Agricultural workers are women or men employed in agricultural activities (farming and cultivation, excluding plantation crops) with or without compensation. Laborers are women or men employed in another person's land for wages in kind or cash. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils excluded). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh, and Jain population. Soil attributes: nitrogen, phosphorus, potassium and pH. See note from Table 2 for a more detailed description.

Table 4: Rural 0-to-6 Sex Ratio and Relative Female Agricultural Labor Force Participation on Soil Texture by Region

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable:					
	Rural 0-to-6 Sex Ratio		Female Agricultural Workers to Total Rural Workers		Female Agricultural Laborers to Total Rural Workers	
	North	South	North	South	North	South
Loamy soils	6.27	25.8	0.034	0.061	-0.016	0.058
	(9.14)	(20.8)	(0.028)	(0.063)	(0.019)	(0.051)
Clayey soils	27.3**	27.6	0.10***	0.12*	0.059**	0.15**
	(10.1)	(20.1)	(0.031)	(0.060)	(0.021)	(0.049)
Loamy soils - Clayey soils	-21.0**	-1.86	-0.071***	-0.061**	-0.074***	-0.087***
	(8.81)	9.76	(0.027)	(0.029)	(0.019)	(0.024)
F-test for soil texture	4.22	0.95	6.02	3.57	8.16	9.53
p-value	0.02	0.39	0.00	0.03	0.00	0.00
R-squared	0.85	0.64	0.70	0.66	0.56	0.60
F	44.88	8.23	17.90	8.97	10.00	6.94
Observations	236	129	236	129	236	129
Variable Means						
Dependent variable	911.8	948.4	0.27	0.33	0.12	0.22
Loamy soils	0.70	0.63	0.70	0.63	0.70	0.63
Clayey soils	0.16	0.31	0.16	0.31	0.16	0.31
Weather	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

* p<0.05, ** p<0.01, *** p<0.001.

Note: Dependent variable: ratio of females per 1000 males in the 0-to-6 age group; ratio of female agricultural workers and agricultural laborers to total workers in rural areas. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils excluded). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh, and Jain population. Soil attributes: nitrogen, phosphorus, potassium and pH. See note from Table 2 for a more detailed description.

Table 5: Rural 0-to-9 Sex Ratio on Soil Texture and Relative Female Agricultural Labor Force Participation by Census Year

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable:					
	Rural 0-to-9 Sex Ratio			Female Agricultural Workers to Total Rural Workers		
	Census Year			Census Year		
	1961	1981	2001[†]	1961	1981	2001
Loamy soils	-8.99	-13.9	2.02	0.024	0.027	0.038
	(9.09)	(10.7)	(8.80)	(0.028)	(0.023)	(0.025)
Clayey soils	5.66	8.10	20.2*	0.076**	0.078**	0.095***
	(9.57)	(11.3)	(9.28)	(0.029)	(0.025)	(0.026)
Loamy soils - Clayey soils	-14.7**	-22.0***	-18.2***	-0.053**	-0.051***	-0.057***
	(7.11)	(8.40)	(6.88)	(0.022)	(0.018)	(0.019)
F-test for soil texture	2.18	3.53	4.12	4.43	6.29	7.68
p-value	0.11	0.03	0.02	0.01	0.00	0.00
R-squared	0.78	0.71	0.81	0.71	0.78	0.70
Observations	365	365	365	365	365	365
Test for change in the effect of texture on sex ratio						
F-test for change since 1961		0.23	0.60		0.00	0.12
p-value		0.79	0.55		1.00	0.89
Variable Means						
Dependent variable	971.9	954.5	924.7	0.28	0.24	0.29
Loamy soils	0.68	0.68	0.68	0.68	0.68	0.68
Clayey soils	0.22	0.22	0.22	0.22	0.22	0.22
Weather	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

* p<0.05, ** p<0.01, *** p<0.001.

Note: Dependent variable: ratio of females per 1000 males in the 0-to-9 age group; ratio of female agricultural laborers to total workers in rural areas. [†] In year 2001 dependent variable is ratio of females per 1000 males in the 0-to-6 age group. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils excluded). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh, and Jain population. Soil attributes: nitrogen, phosphorus, potassium and pH. See note from Table 2 for a more detailed description.

Table 6: Rice and Wheat Yield and Cultivated Area and Per-Capita Household Expenditure on Soil Texture

	(1)	(2)	(3)	(4)	(5)
	Dependent Variable:				
	Rice Yield	Wheat Yield	Rice to Wheat Yield	Rice to Wheat Area	Per-Capita Household Expenditure
Loamy soils	44.2	624.5***	-0.055	1811.6	-5.67
	(198.2)	(187.3)	(0.50)	(6718.8)	(20.0)
Clayey soils	-83.6	520.9**	-0.47	7404.7	-12.1
	(209.0)	(197.4)	(0.53)	(7077.0)	(21.1)
Loamy soils - Clayey soils	127.8	103.6	0.42	-5593.1	6.43
	(155.0)	(146.4)	(0.37)	(5532.3)	(15.6)
F-test for soil texture	0.34	5.63	0.74	0.73	0.18
p-value	0.71	0.00	0.48	0.48	0.84
R-squared	0.75	0.86	0.47	0.10	0.74
F	29.93	59.57	7.30	0.96	27.67
Observations	365	365	297	309	358
<u>Variable Means</u>					
Dependent variable	1715.4	1821.1	1.08	1659.7	428.2
Loamy soils	0.68	0.68	0.67	0.66	0.68
Clayey soils	0.22	0.22	0.23	0.23	0.22
Weather	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes

* $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Note: Dependent variables: rice and wheat yield (in t/ha), ratio of rice to wheat yield, ratio of rice to wheat cultivated area, and median per-capita household expenditure (in real Rs). Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils excluded). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh, and Jain population. Soil attributes: nitrogen, phosphorus, potassium and pH. See note from Table 2 for a more detailed description.

Table 7: Proxies of Deep Plow Agriculture by Soil Texture

	(1)	(2)	(3)	(4)	(5)	(6)
	All Districts	Relative to Sandy Soils Loamy	Clayey	(2)-(3)	R-Squared	Obs.
Panel A: Livestock and Agricultural Equipment Used in Land Preparation						
Buffaloes, per ha of land	0.78	0.35*	-0.061	0.41***	0.71	331
	[0.82]	(0.17)	(0.18)	(0.14)		
Cattle, horses, donkeys, mules,	1.04	0.11	0.17	-0.064	0.50	331
and asses, per ha of land	[0.70]	(0.19)	(0.20)	(0.15)		
Heavy plows, per ha of land	1.78	0.39	-0.34	0.73**	0.71	331
	[2.01]	(0.43)	(0.45)	(0.34)		
Light plows, per ha of land	0.31	-0.044	-0.077	0.033	0.37	331
	[0.27]	(0.086)	(0.090)	(0.068)		
Soil levelers, per ha of land	0.11	0.014	-0.033	0.048	0.55	331
	[0.14]	(0.038)	(0.039)	(0.030)		
Panel B: Agricultural Equipment Used in Cultivation						
Seed planters, per ha of land	0.014	0.0031	0.0087	-0.0055	0.19	331
	[0.027]	(0.0097)	(0.010)	(0.0077)		
Wheel and blade hoes, per ha of land	0.18	0.12	-0.0029	0.12	0.31	331
	[0.37]	(0.12)	(0.13)	(0.096)		
Weeders, per ha of land	0.20	0.00055	-0.11	0.11	0.64	331
	[0.40]	(0.096)	(0.10)	(0.076)		
Harvesters, per ha of land	0.22	0.0012	0.000035	0.0011	0.54	331
	[0.42]	(0.11)	(0.12)	(0.090)		
Panel C: Agricultural Workers by Task (Task Take-Up)						
Workers in land preparation,	0.17	0.088	-0.014	0.10***	0.18	358
as % of all workers	[0.15]	(0.052)	(0.055)	(0.038)		
Workers in cultivation,	0.86	-0.11*	-0.0032	-0.11***	0.19	358
as % of all workers	[0.16]	(0.053)	(0.056)	(0.039)		
Panel D: Agricultural Workers by Task and Gender (Task Segregation by Gender)						
Females in land preparation,	0.014	0.012	0.010	0.0019	0.19	358
as % of all workers	[0.027]	(0.0091)	(0.0096)	(0.0067)		
Females in cultivation,	0.31	0.014	0.056	-0.043	0.66	358
as % of all workers	[0.18]	(0.046)	(0.048)	(0.034)		
Males in land preparation,	0.16	0.076	-0.024	0.100***	0.19	358
as % of all workers	[0.14]	(0.049)	(0.052)	(0.036)		
Males in cultivation,	0.55	-0.12*	-0.059	-0.065	0.55	358
as % of all workers	[0.21]	(0.059)	(0.062)	(0.043)		

* p<0.05, ** p<0.01, *** p<0.001.

Note: Column 1 reports average and standard deviation. Columns 2 and 3 report coefficients from the regression of indicated variables on the fraction of district area in loamy and clayey soils (excluded category: sandy soils), conditional on state fixed effects. Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh, and Jain population. Soil attributes: nitrogen, phosphorus, potassium and pH. See note from Table 2 for a more detailed description. Column 4 reports the difference between the coefficients in columns 2 and 3.

Table 8: IV Regression of Rural 0-to-6 Sex Ratio on Relative Female Agricultural Labor Force Participation (Instruments: Soil Texture Fractions)

	(1)	(2)	(3)	(4)	(5)	(6)
	Second Stage Dependent Variable: Rural 0-to-6 Sex Ratio					
	Female Agricultural Workers to Total Rural Workers			Female Agricultural Laborers to Total Rural Workers		
	All	North	South	All	North	South
Female agricultural to total rural workers	281.7***	340.6***	142.5***	439.2***	539.3***	234.0***
	(33.6)	(42.9)	(42.5)	(55.5)	(105.7)	(54.4)
R-squared	0.74	0.79	0.51	0.72	0.76	0.51
F	36.14	39.76	6.79	33.30	33.26	7.15
Observations	365	236	129	365	236	129
Variable Means						
Dependent variable	924.7	911.8	948.4	924.7	911.8	948.4
Female labor	0.29	0.27	0.33	0.16	0.12	0.22
Weather	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

* p<0.05, ** p<0.01, *** p<0.001.

Note: Second stage dependent variable: ratio of females per 1000 males in the 0-to-6 age group. Second stage main explanatory variables: ratio of female agricultural workers and agricultural laborers to total workers in rural areas. First stage: see Table 3 and Table 4. Instruments: fractions of district area in loamy and clayey soils (sandy soils excluded). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh, and Jain population. Soil attributes: nitrogen, phosphorus, potassium and pH. See note from Table 2 for a more detailed description. See Table 4 for first stage and reduce form regressions.

FOR ONLINE PUBLICATION

Appendix

Data Sources

Soils of India. National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), Indian Council of Agricultural Research. Data on soil taxonomy, physiography, depth, parent material, particle size, surface texture classification and particle percentage are reported for 9875 soil type divisions. Divisions result from the intersection of a data layer of soil attributes and district boundaries from the 2001 Census of India. Soil inventory follows a three tier approach including remote-sensing, soil survey and chemical analysis, and GIS application for mapping and image interpretation.

Agricultural Census and Input Survey, 2000-01. Department of Agriculture and Cooperation (DAC), Ministry of Agriculture. Data are compiled by operational holding and reported at the district level as on 1991. Data include district number and area of operational holdings, land utilization, tenancy pattern, cropping pattern, irrigation status, fertilizer, manure and pesticide use, agricultural machinery and equipment, livestock and agricultural credit.

Census of India, Primary Census Abstract and Religion Tables, 2001. Office of the Registrar General of India (RGI) and Census Commissioner. Population and demographic information is available as cross-tabulations. No raw micro-data are accessible to the public. Enumeration totals are provided for the entire population and for population in the 0-6 age group. Data are reported for 593 districts.

National Sample Survey (NSS), 55th Round, 1999-2000. National Sample Survey Organization (NSSO). The 55th round of the NSS is the sixth quinquennial survey in the series on household consumer expenditure, employment, and unemployment. It has all India coverage and representation at the regional level. Data are reported for 71,417 households in 537 districts and 264 regions as on 1991.

Daily District-wise Normals of Meteorological Parameters. Indian Meteorological Department (IMD). Data include 24-hour cumulative rainfall precipitation and number of rainy days; maximum, minimum and mean temperature; relative humidity; total cloud amount and wind speed. Rainfall normals are computed for 524 districts using 50 years of data (1941-1990). Other normals are prepared for 441 districts using 30 year of data (1971-2000).

Indian Agricultural Statistics, 1997-2001. Department of Agriculture and Cooperation (DAC), Ministry of Agriculture. District-wise data include yearly crop production, yield and area cultivated, land classification, irrigated area (source-wise and crop-wise), and farm harvest prices of principal crops.

Consumer Price Index Numbers for Agricultural and Rural Laborers, 1999-2001. Labor Bureau of India. State-wise CPI(RL) and CPI(AL) are constructed using retail prices of 260 items of goods and services. Information is collected on a monthly basis by the National Sample Survey Organization from 600 sample villages in 20 states.

India Administrative Atlas 1872-2001. Office of the Registrar General of India (RGI) and Census Commissioner. This publication contains administrative division maps of India for each decade, historical background on the administrative divisions that occurred during the period, data appendixes and an equivalence table that permits to trace the constituents of a district during different decades.

Table A.1: Rural 0-to-6 Sex Ratio on Soil Texture

	(1)	(2)	(3)	(4)	(5)
			Dependent Variable: Rural 0-to-6 Sex Ratio		
Loamy soils	45.5***	40.8***	29.3***	2.02	31.3***
	(7.19)	(8.34)	(7.78)	(8.54)	(7.64)
Clayey soils	52.7***	58.6***	47.7***	20.2*	47.6***
	(7.41)	(8.54)	(7.86)	(9.01)	(7.79)
Loamy soils - Clayey soils	-7.27	-17.8***	-18.3***	-18.2***	-16.3***
	(5.81)	(6.96)	(6.31)	(6.68)	(6.24)
F-test for soil texture	27.31	23.65	18.49	4.37	18.66
p-value	0.00	0.00	0.00	0.01	0.00
R-squared	0.70	0.71	0.77	0.81	0.79
F	35.23	32.63	35.72	41.57	37.47
Observations	577	436	436	365	421
Variable Means					
Dependent variable	934.1	928.7	928.7	924.7	929.1
Loamy soils	0.66	0.66	0.66	0.68	0.66
Clayey soils	0.22	0.22	0.22	0.22	0.22
Weather	No	Yes	Yes	Yes	Yes
Demographics	No	No	Yes	Yes	Yes
Income and assets	No	No	No	No	Yes
Crop yield	No	No	No	No	Yes
Soil nutrients and pH	No	No	No	Yes	No
State fixed effects	Yes	Yes	Yes	Yes	Yes

* p<0.05, ** p<0.01, *** p<0.001

Note: Dependent variable: ratio of females per 1000 males in the 0-to-6 age group. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils excluded). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh, and Jain population. Income and assets: median per capita household expenditure (in real Rs), percentage households that own cultivated land and average area owned (in ha). Crop yield: rice yield and wheat yield (in tons/ha). Soil attributes: nitrogen, phosphorus, potassium and pH. See note from Table 2 for a more detailed description.